REPORT #
RRTAC 89-1

Reclamation Research Annual Report — 1988

Heritage Fund

Alberta

LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

DISCLAIMER

This report is intended to provide government and industry staff with up-to-date technical information to assist in the preparation and review of Development and Reclamation Approvals, and development of guidelines and operating procedures. This report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

Additional information on the Reclamation Research Program and additional copies of this report may be obtained by contacting:

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Report No. RRTAC 89-1

RECLAMATION RESEARCH

ANNUAL REPORT - 1988

Prepared by

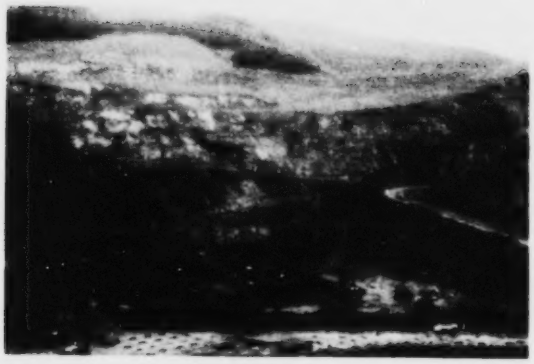
The Reclamation Research Technical Advisory Committee

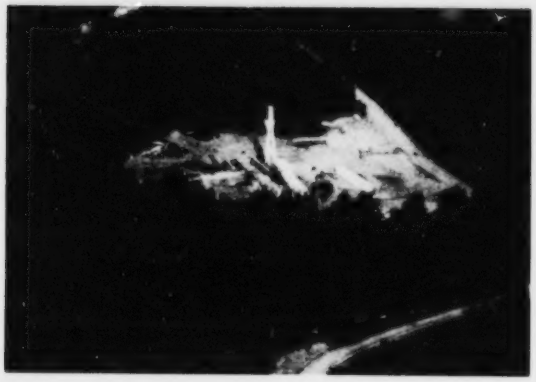
for the

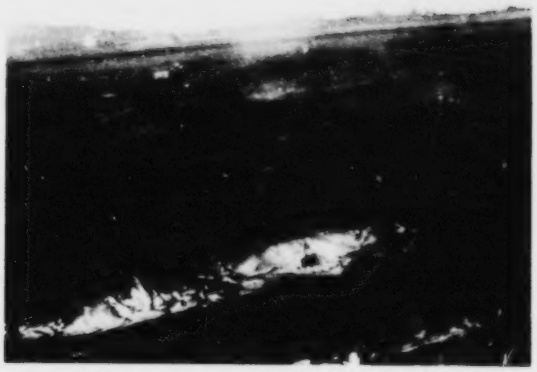
ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL

1989

Reclamation Research Technical Advisory Committee







Mission: To coordinate and foster reclamation research in Alberta.

Members: Chris Powter (Chairman) - Alberta Environment; Sharon Guenette (Secretary) - Alberta Forestry, Lands and Wildlife; Leon Marciak - Alberta Agriculture; Reinhard Hermesh - Alberta Environmental Centre; David Lloyd - Alberta Forestry, Lands and Wildlife; Sam Takyi - Alberta Forestry, Lands and Wildlife; Hugh Wollis - Alberta Forestry, Lands and Wildlife; Harry Sahay - Alberta Energy; Stephen Moran - Alberta Research Council.

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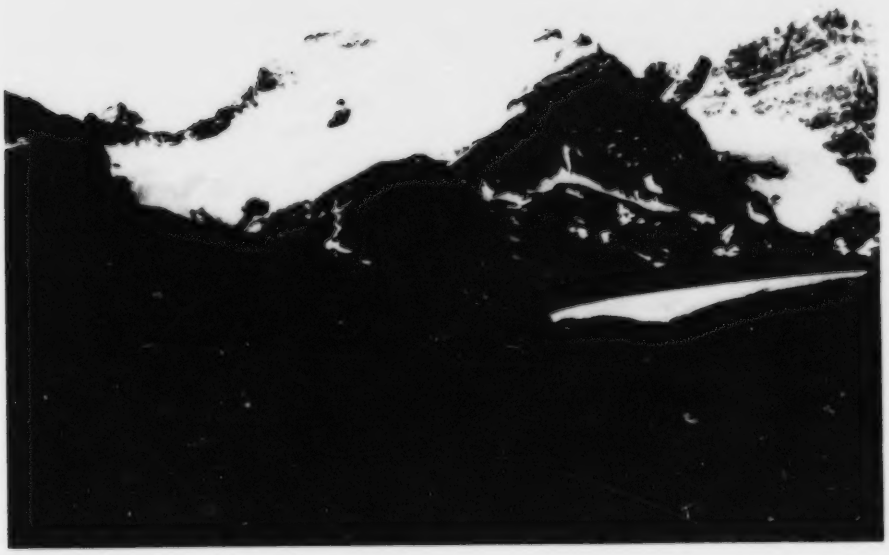

1. INTRODUCTION

Regulating surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of Environment (Mr. John King, Director, Land Reclamation Division) and two deputy chairmen from the Department of Forestry, Lands and Wildlife (Mr. Roger Marvin, Director, Land Management and Development Branch and Mr. Don Fregren, Director, Forest Land Use Branch). Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The Reclamation Research Program was established in 1978 to identify the most efficient methods for achieving acceptable reclamation in Alberta. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund, Land Reclamation Program.

To assist with the development and administration of the research program, the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee consists of eight members and a secretary:

Chris Powter (Chairman) - Alberta Environment, Land Reclamation Division

Sharon Guenette (Secretary) - Alberta Forestry, Lands and Wildlife, Forest Land Use Branch

Leon Marciak - Alberta Agriculture, Conservation and Development Branch

Reinhard Hermesh - Alberta Environmental Centre, Plant Sciences Division

David Lloyd - Alberta Forestry, Lands and Wildlife, Public Lands Division

Sam Takyi - Alberta Forestry, Lands and Wildlife, Alberta Forest Service

Hugh Wollis - Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division

Harry Sahay - Alberta Energy, Scientific and Engineering Services and Research Division

Stephen Moran - Alberta Research Council, Terrain Sciences Division.

RRTAC's mission is to coordinate and foster reclamation research in Alberta. To this end, the Committee updates priorities, reviews research proposals, and organizes workshops.

1.1 PROGRAMS

RRTAC conducts research in four major program areas, which correspond to Alberta's major industrial activities and biophysical regions: Plains Coal, where agricultural concerns are dominant; Mountains and Foothills Coal, where recreation, forestry, wildlife and watershed concerns are the focus; Oil Sands, where wildlife and forestry concerns exist; and, Oil and Gas, where agricultural and forestry concerns are examined.

While it is expected that research results will often have province-wide application, the division of the research among the four programs has proven helpful in identifying priorities and directions.

The objectives of the research projects are:

1. To develop methods that will make reclamation a more efficient and effective process;
2. To provide scientific data to enable sound decision making in the regulatory and operational reclamation stages; and,

3. To provide scientific data to evaluate the effectiveness of reclamation guidelines and criteria.

RRTAC research projects are trials for new technologies, and new proposals are reviewed and rated on their adherence to priorities, likelihood of success and competence of researchers. Throughout the review process, the key question is: "Would this information make reclamation in Alberta a more efficient process?"

1.2 MANAGEMENT AND FUNDING

In addition, every effort is made to involve industry in management and funding of the research to ensure the projects address real field concerns. Cooperation with industry facilitates agreement on reclamation research priorities and early implementation of required changes in operations and planning.

The following companies and agencies were involved with the design and management of RRTAC projects this year:

Agriculture Canada
Alberta Agriculture
Alberta Energy - Scientific and Engineering Services and Research Division
Alberta Energy Resources Conservation Board
Alberta Environment - Land Reclamation Division
Alberta Environment - Wastes and Chemicals Division
Alberta Environmental Centre - Environmental Technology Division
Alberta Environmental Centre - Plant Sciences Division
Alberta Forestry, Lands and Wildlife - Alberta Forest Service
Alberta Forestry, Lands and Wildlife - Fish and Wildlife Division
Alberta Forestry, Lands and Wildlife - Public Lands Division
Alberta Power Limited
Alberta Research Council - Terrain Sciences Division
Bow Valley Industries Ltd.
Cardinal River Coals Ltd.
Crows Nest Resources Limited
Esso Resources Canada Ltd.
Fording Coal Ltd.
Gregg River Resources Ltd.
Luscar Ltd.
Luscar Sterco (1977) Ltd.
Manalta Coal Ltd.
NOVA Corporation of Alberta
Obed Mountain Coal Company Limited
Peace Pipe Line Ltd.
Shell Canada Resources Limited
Smoky River Coal Ltd.
Suncor Inc.
Syncrude Canada Limited
TransAlta Utilities Corporation

The following agencies and companies provided additional research funding for RRTAC projects this year:

Alberta Environmental Centre
Alberta Recreation, Parks and Wildlife Foundation
Alberta Research Council
Syncrude Canada Limited

1.3 SIGNIFICANT EVENTS IN 1988

This year marked several important changes and events in the Program. Of greatest significance was the extension for five years to the Land Reclamation Program, which was announced in the Throne Speech in February, 1989. This extension allows RRTAC to undertake some long range planning, and provides the ability to enter into long-term projects.

Dr. Glen Singleton, who had been Chairman of RRTAC since April, 1987, resigned in December to devote full-time to his new position as Head of the Recycling Branch within Alberta

Environment. Mr. Chris Powter, of the Land Reclamation Division, Alberta Environment, was appointed Acting Chairman in February.

The Canadian Petroleum Association and the Independent Petroleum Association of Canada were approached to provide members for the Oil and Gas Reclamation Research Program. They responded positively. This now means that all the Programs are jointly managed by government and industry representatives.

1.4 REPORTS

Upon project completion, a final report is submitted. Some final reports are published intact as RRTAC Reports and released to the public. Others are held, pending their inclusion in comprehensive RRTAC Reports. Since 1978, RRTAC has produced over 50 reports and workshop proceedings on a wide variety of topics. The reports are available at a small cost from Publication Services, Queen's Printers, 11510 Kingsway Avenue, Edmonton, Alberta T5G 2Y5. Section 9 provides a listing of available reports.

1.5 CONTENTS OF THIS REPORT

Following is a summary of the most recent research projects as of March 31, 1989. Budget details are given in Section 8. Information on previous projects is given in Section 7 and in previous annual reports.

Additional information on the Reclamation Research Program may be obtained by contacting:

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Reclamation Research Technical Advisory Committee
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9820 - 106 Street
EDMONTON, Alberta
T5K 2J6

Telephone: (403) 427-4147

2. PLAINS COAL RECLAMATION RESEARCH PROGRAM

The Plains Coal Reclamation Research Program (PCRRP) has been designed by the provincial government and members of the coal industry to answer questions relating to groundwater and soil reconstruction in plains coal mining zones. Efforts are focused in two main areas:

1. Soil reconstruction will indicate how to rebuild agricultural soils after mining; and,
2. Hydrology will describe what happens to groundwater during mining and after reclamation, and how to rebuild the landscape to maximize the agricultural potential.

The Program has been jointly managed by the provincial government and coal industry personnel. The projects are also funded by both industry and government. For example, Alberta Power Limited, Luscar Ltd., Manalta Coal Ltd. and TransAlta Utilities Corporation constructed the test plots at the Battle River and Highvale sites, while research and maintenance activities are supported by the provincial government.

2.1 RECLAMATION OBJECTIVES

To return cropland to pre-mining levels of capability which includes both agricultural and hydrologic capabilities.

2.2 THE PROBLEM

Coal is surface mined in two major zones in Alberta: the Ardley Zone running southeast from Mayerthorpe to Red Deer, and the Horseshoe Canyon Zone which runs parallel and to the east from Barrhead through Camrose to Drumheller (Figure 1). The Ardley Zone is surface mined near Lake Wabamun to provide coal to the Wabamun, Sundance, Keephills, and Genessee power plants. The Horseshoe Canyon Zone is mined on either side of the Battle River between Forestburg and Halkirk. These mines supply the Battle River Generating Station. Another power plant and mine have been developed to the south of Sheerness.

Plains coal seams are usually overlain by bedrock which contain a high proportion of swelling clays. When exposed to the elements, the bedrock shales and sandstones break down into a material that is sticky when wet and very hard when dry. This severely hinders plant growth and agricultural operations. Above the bedrock lie glacial deposits which are usually free of the most adverse properties of the bedrock though they lack the plant nutrients and organic matter which are characteristic of the overlying topsoil.

Rebuilding a soil profile is one of the major problems in cropland reclamation in Alberta. A soil must be built on levelled overburden which will have similar capability to the original soil. Existing evidence indicates that placing topsoil and a buffering material over the spoil is the most efficient method for achieving this goal (Figure 2). However, we do not know exactly how much capping material is needed in order to bring back the original level of agricultural capability. Also, when topsoils or subsoils are in short supply, other amendments may be useful in constructing a suitable rootzone medium. In addition to soil reconstruction, certain agricultural practices like green manuring and legume cropping may help rebuild the soil.

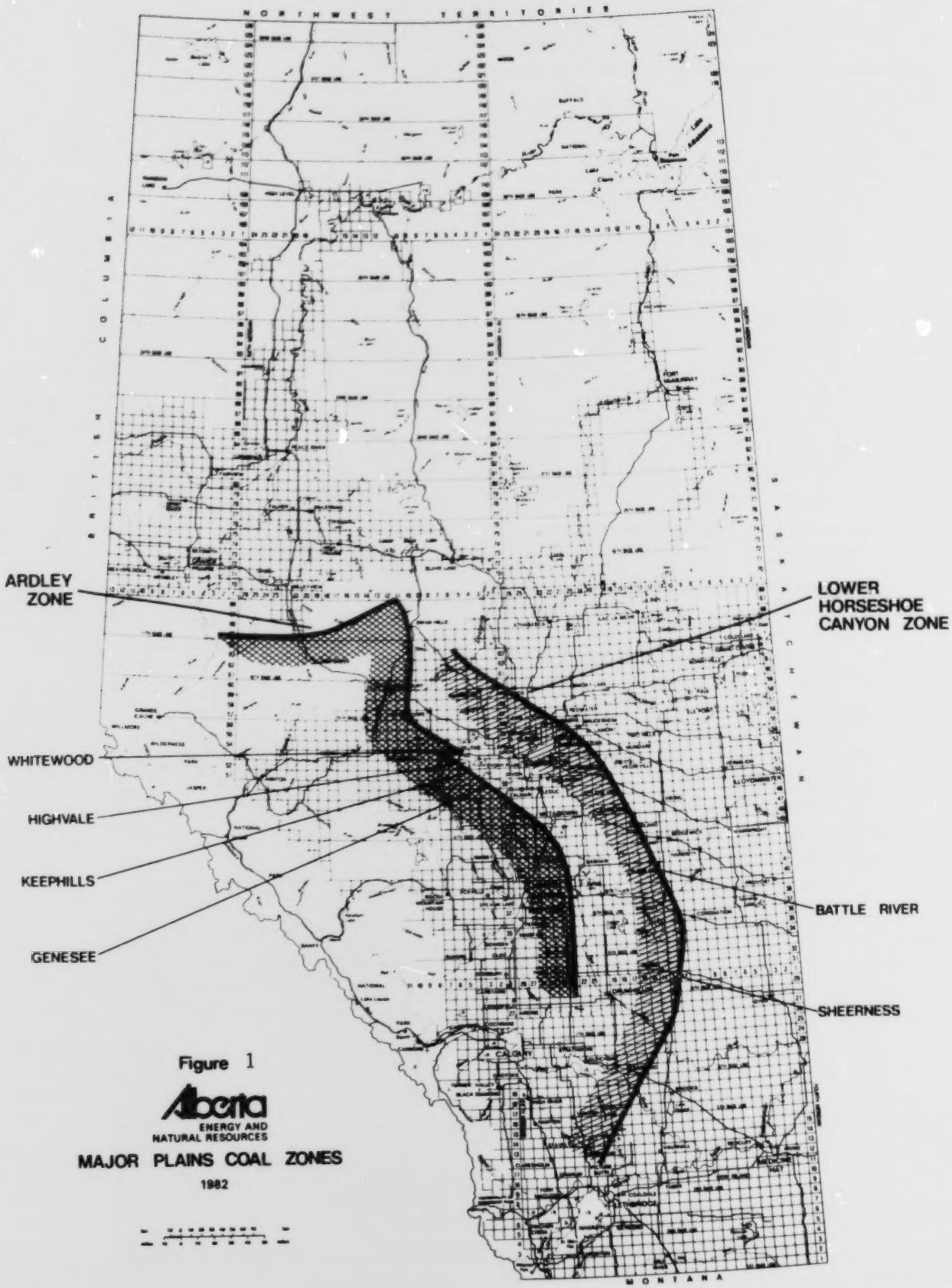


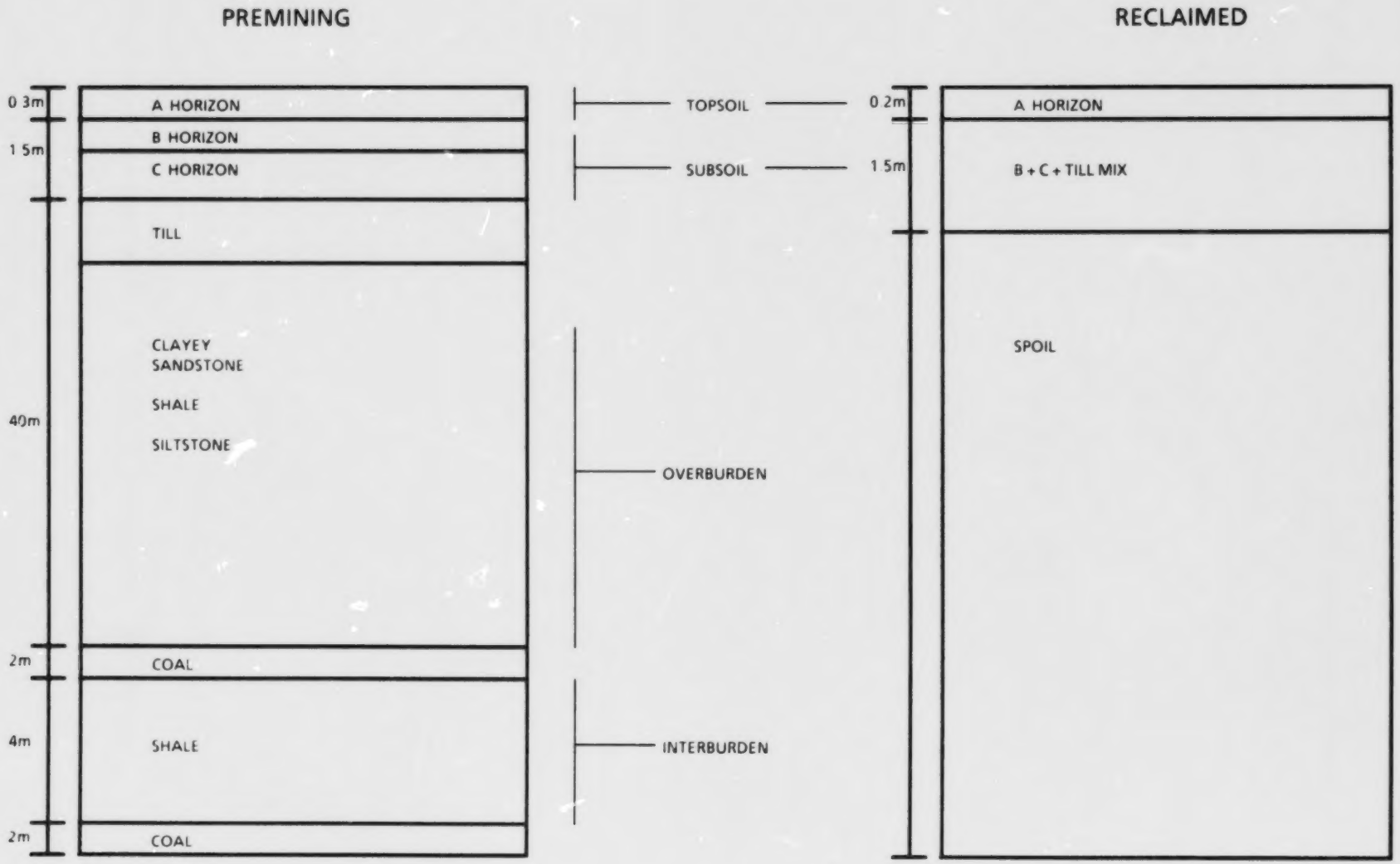
Figure 1

Alberta
ENERGY AND NATURAL RESOURCES

MAJOR PLAINS COAL ZONES

1982

FIGURE 2 - GENERALIZED PROFILES



In many plains areas, the coal seams are the major source of domestic water. What will happen when the coal is removed and overburden fills the mined-out pit? The behaviour of the post-mining groundwater system will affect water users and could influence future agricultural potential. However, prior to the Plains Coal Reclamation Research Program, little was known about the effects of surface mining on groundwater in Alberta.

2.3 RESEARCH APPROACH

Mining in the Ardley and Horseshoe Canyon Coal zones involves two different sets of soils, overburden and climate. Also, soil reconstruction and groundwater cannot be studied in isolation. For example, if after mining, a saline watertable re-establishes within a meter of the soil surface, the rootzone may become unsuitable for crops regardless of its original quality. In both the Ardley and Horseshoe Canyon zones the best methods of reconstructing soils are being identified and at the same time, mining effects on groundwater are being studied.

By combining the results of these experiments, we can come to understand how mined landscapes function and how they can be designed to ensure a return to their original value.

2.4 SOIL RECONSTRUCTION

2.4.1 Battle River Soil Reconstruction Project - L. Leskiw, Can-Ag Enterprises Ltd.

Grain and forage yields have been evaluated on a series of soil reconstruction plots in the Battle River (Figures 3a and b) mining area.

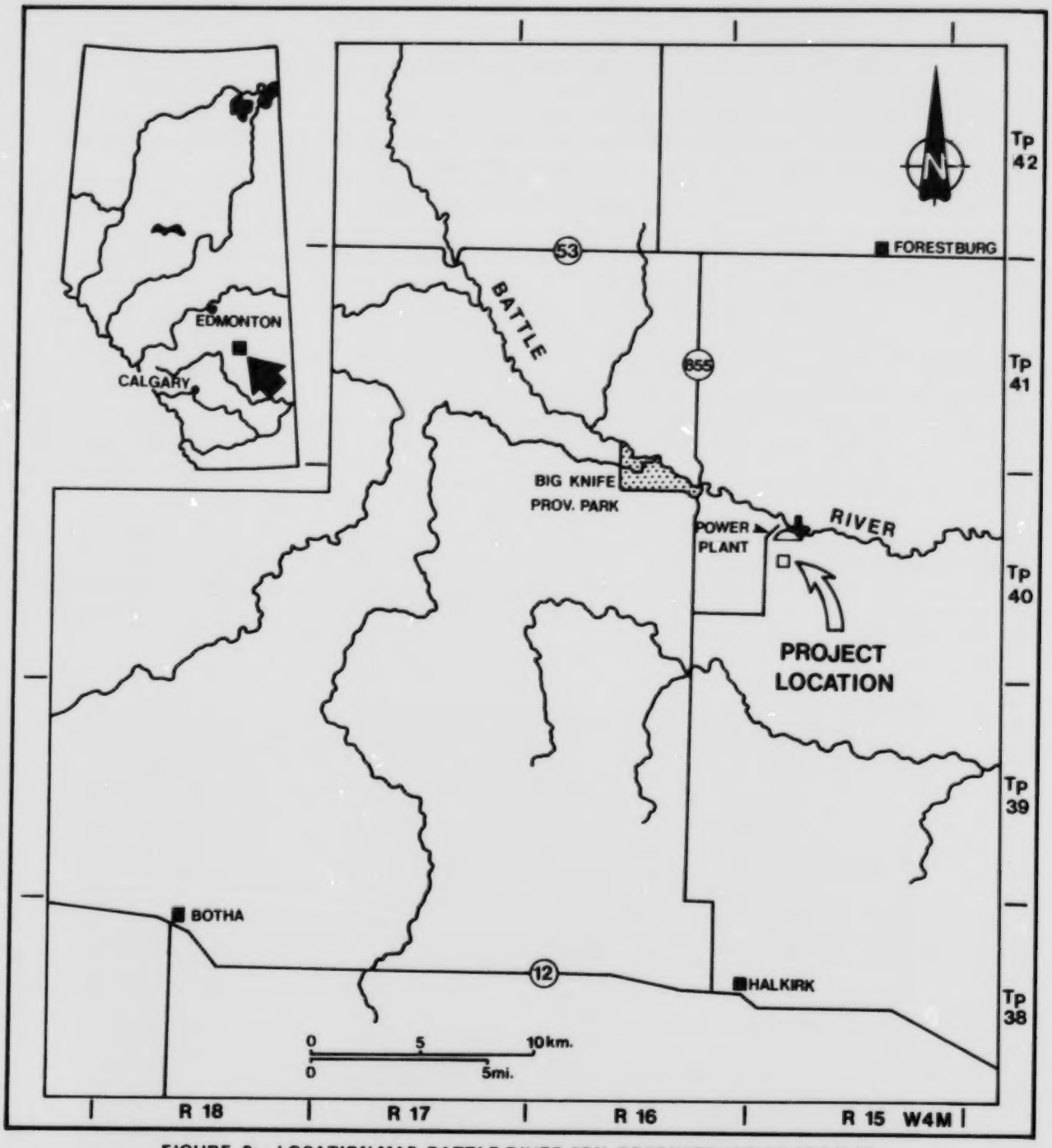


FIGURE 3a. LOCATION MAP, BATTLE RIVER SOIL RECONSTRUCTION PROJECT

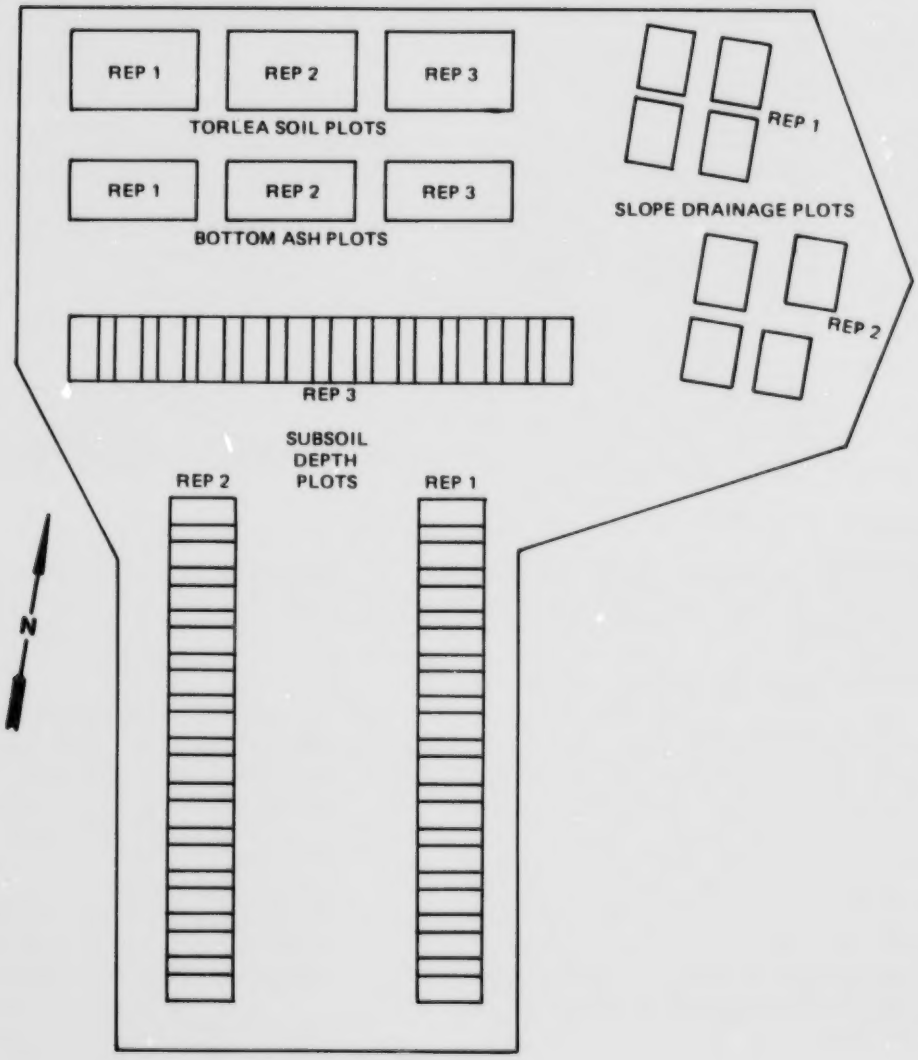


FIGURE 3b COMPOUND LAYOUT, BATTLE RIVER SOIL RECONSTRUCTION PROJECT

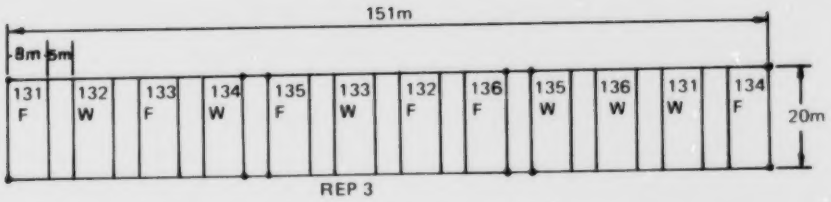
Treatments included: depth of subsoil (0 to 3.35 m thicknesses) over sodic spoil (Figure 3c), reconstruction of solonetzic soils (Figure 3d), and use of bottom ash and gypsum as amendments to sodic spoil (Figure 3e). Salt movement and crop growth on spoil slopes were also studied (Figure 3f). Cropping and soil sampling began at Battle River in 1982.

Status: The project is completed and a five-year summary report is being prepared. Over the next two years, the plots will be fallowed and replanted to forages to allow for potential collection of data at a later date.

2.4.2 Highvale Soil Reconstruction Project - L.A. Panek, Monenco Consultants Ltd.

The Highvale Soil Reconstruction Project (Figure 4a) was initiated in 1982 by government and coal industry representatives to provide interpretive data for reclamation planning and post-mine land management of sodic strip-mined soils. The project objectives were to: (1) determine the optimum depth of subsoil replacement over sodic minespoil to ensure adequate crop productivity; (2) examine slope configurations which could minimize soil quantities needed to restore the original capability of reclaimed land; and, (3) assess the sustainability of crop production on soil replaced over sodic minespoil by monitoring upward soluble salt migration into the rootzone.

A subsoil depth experiment was established to determine suitable subsoil thicknesses (0.00, 0.55, 0.95, 1.35, 1.85 and 3.45 m underlying 15 cm of topsoil) for reclaiming sodic minespoil and maximizing production of an annual barley cereal crop or a perennial alfalfa-smooth bromegrass forage mixture (Figure 4b). A slope experiment was established to determine the effects of slope types (5^{o} and 10^{o} slopes, north and south



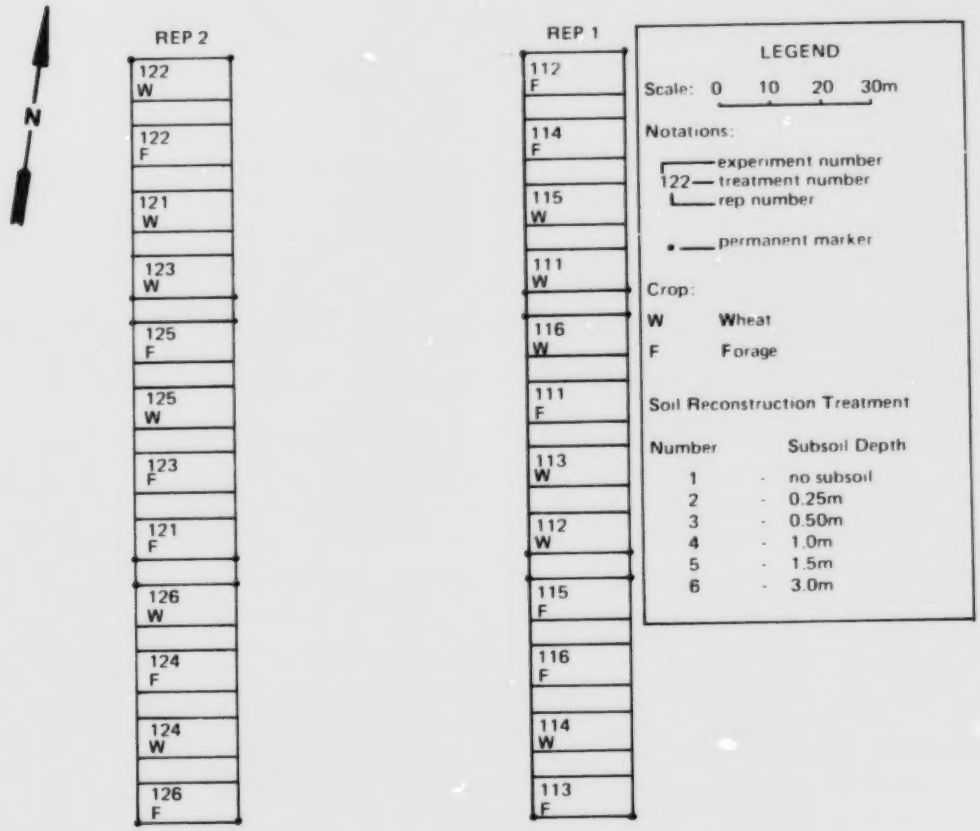


FIGURE 3c. PLOT LAYOUT – SUBSOIL DEPTH EXPERIMENT, BATTLE RIVER SOIL RECONSTRUCTION PROJECT

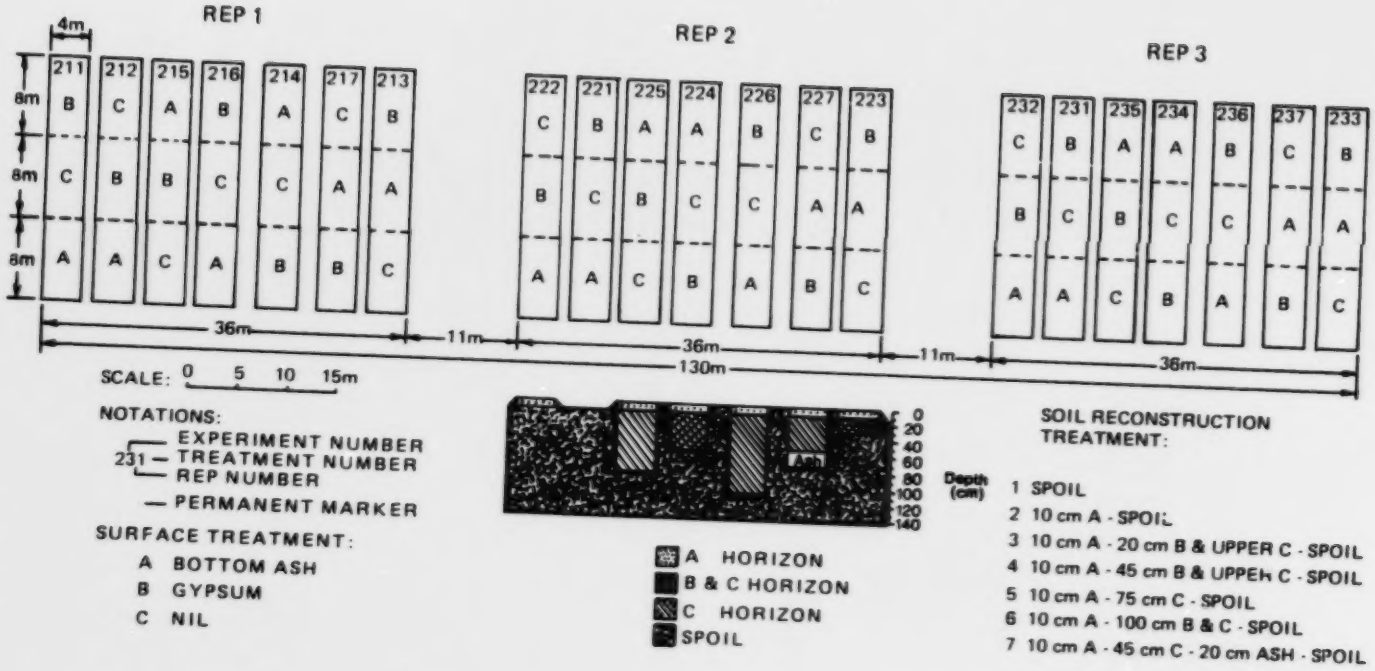


FIGURE 3d. PLOT LAYOUT – TORLEA SOIL EXPERIMENT, BATTLE RIVER SOIL RECONSTRUCTION PROJECT

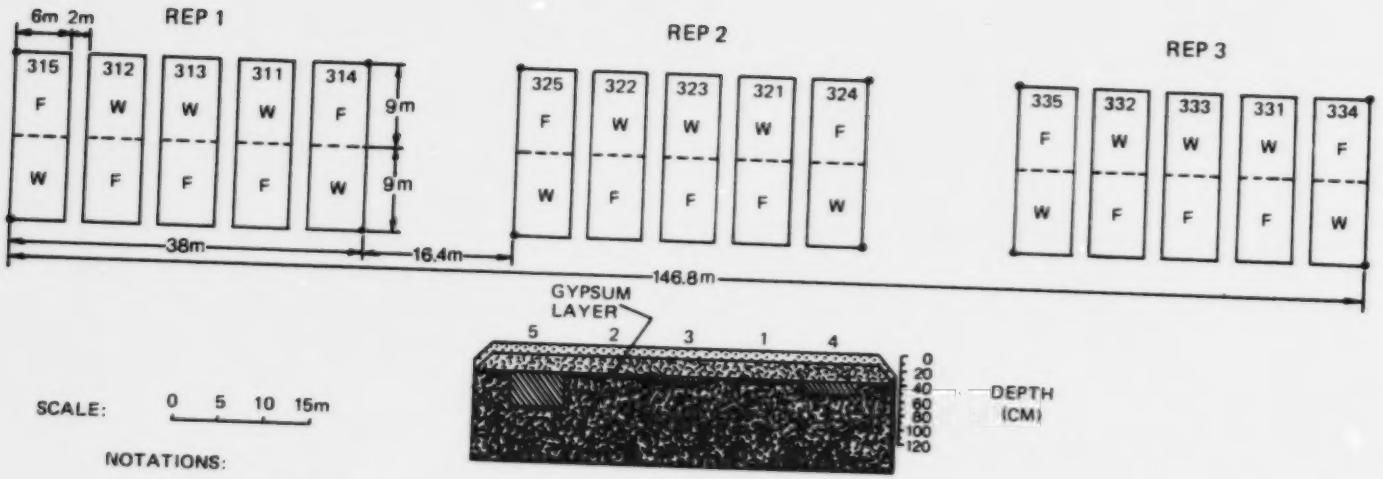
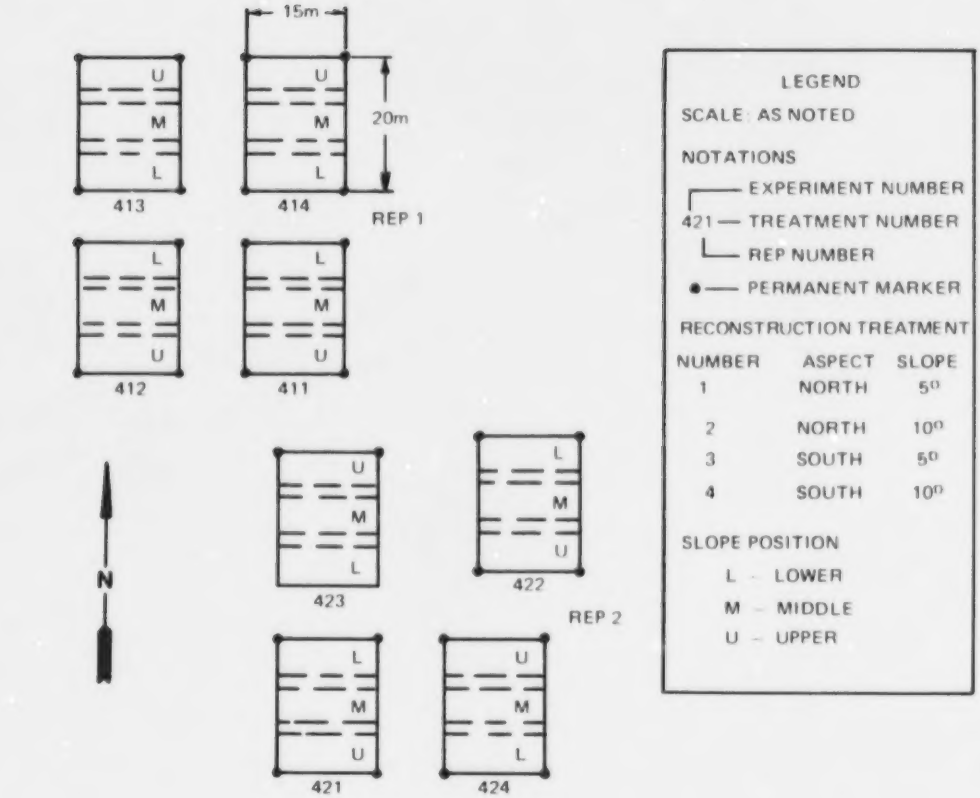


FIGURE 3e. PLOT LAYOUT – BOTTOM ASH EXPERIMENT, BATTLE RIVER SOIL RECONSTRUCTION PROJECT



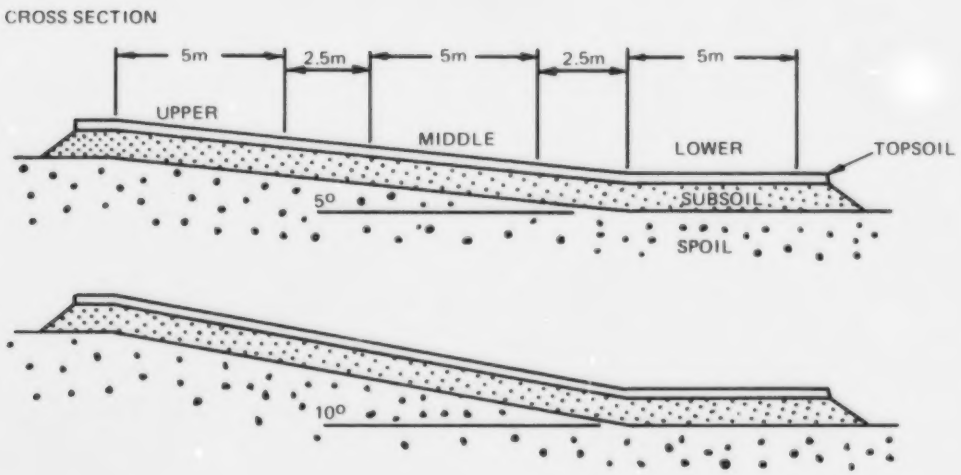
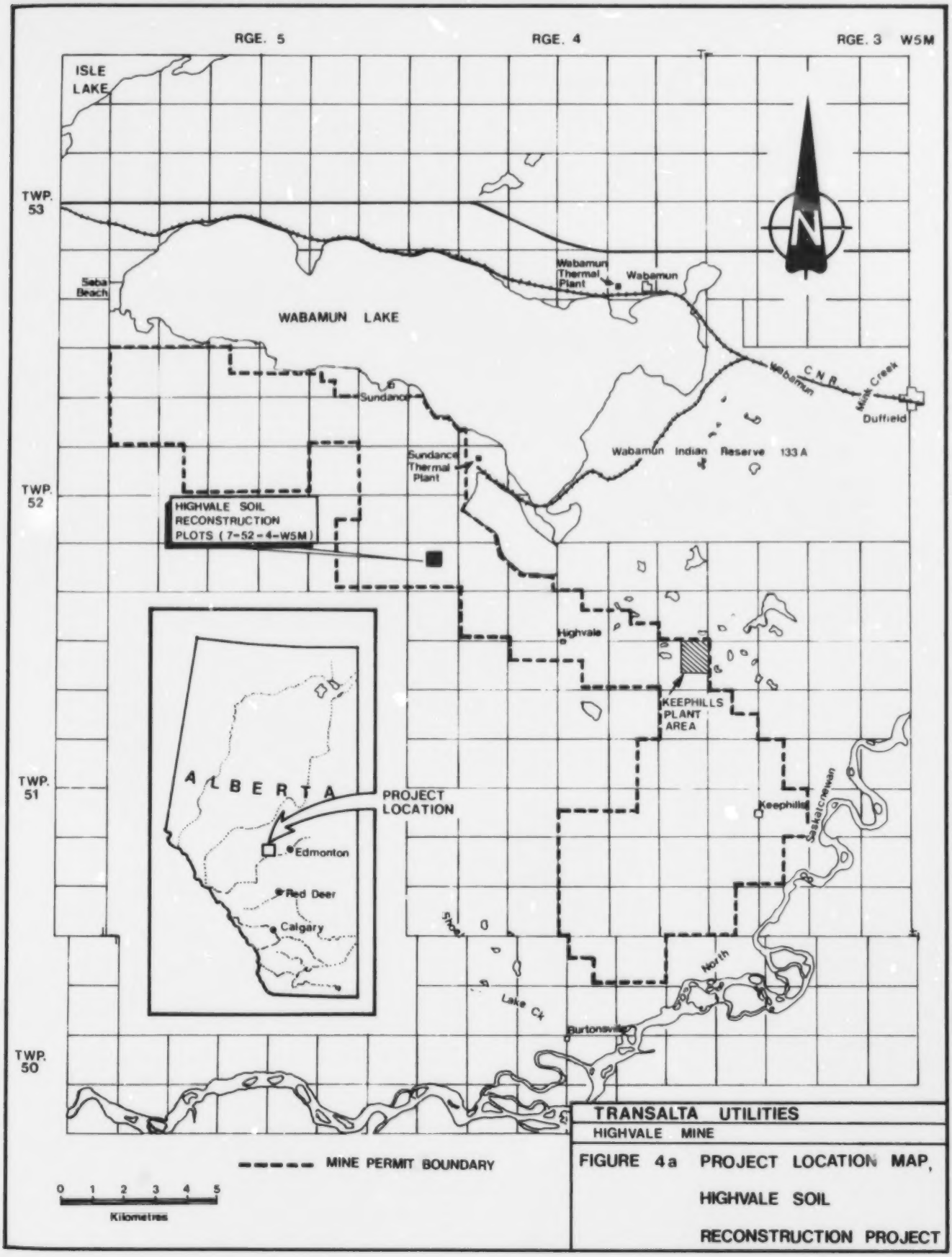


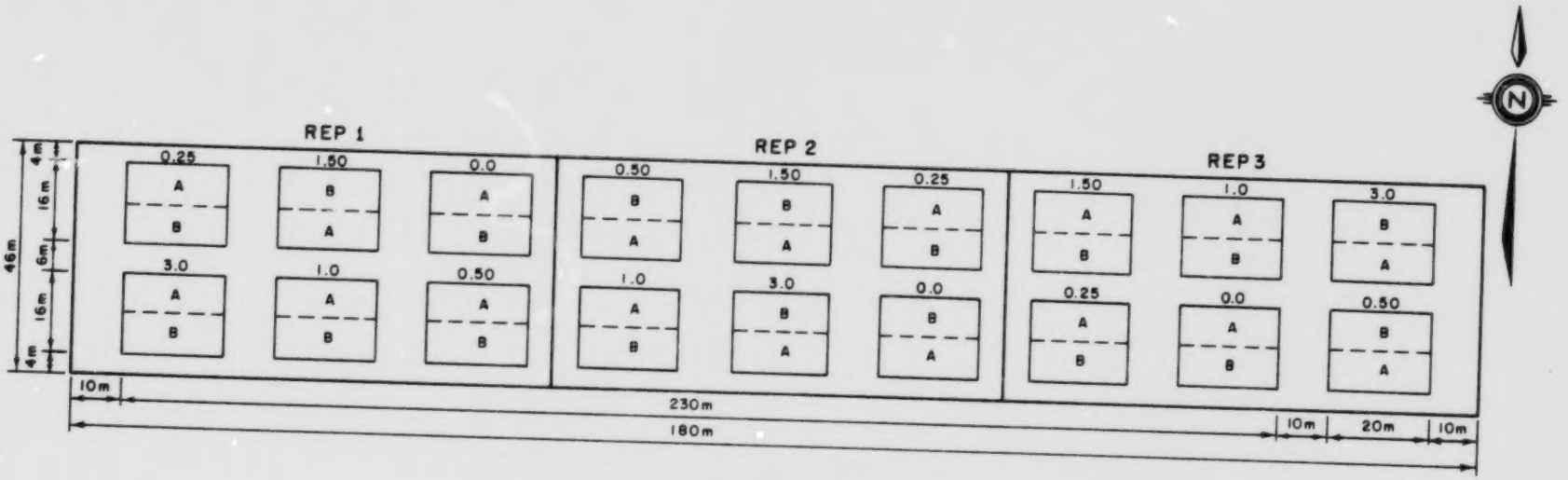
FIGURE 3f. PLOT LAYOUT – SLOPE DRAINAGE EXPERIMENT, BATTLE RIVER SOIL RECONSTRUCTION PROJECT



TRANSALTA UTILITIES

HIGHVALE MINE

FIGURE 4a PROJECT LOCATION MAP, HIGHVALE SOIL RECONSTRUCTION PROJECT



A - ALFALFA (Rambler) AND BROMEGRASS (Charlton)
B - BARLEY (Klondike)
0.0 NO SUBSOIL
0.25 0.25m SUBSOIL
0.50 0.50m SUBSOIL
1.00 1.00m SUBSOIL
1.50 1.50m SUBSOIL
3.00 3.00m SUBSOIL

FIGURE 4b.

HIGHVALE SOIL RECONSTRUCTION PROJECT

SUBSOIL EXPERIMENT
LAYOUT

aspects) and slope positions (lower, mid and upper) on alfalfa-smooth bromegrass crop productivity (Figure 4c). Soil water movement, salt/sodium migration, and bulk density were monitored in both experiments.

For the subsoil depth experiment, crop yields increased as subsoil thickness increased from 0.00 to 0.55 m, while optimum yields were generally achieved with the replacement of at least 0.95 m of subsoil. The forage crop developed a deeper effective rootzone, had better root penetration into minespoil and reduced soil bulk density more than the barley crop. Soil moisture levels above the subsoil/minespoil interface tended to decline over time under forage, likely due to higher consumptive use of soil moisture compared to the barley crop. The potential for moisture accumulation above the interface when seeded to barley may enhance upward migration of soluble sodium, although movement has generally been limited to the first 15 cm increment above minespoil after five years. For the slope experiment, forage yield was generally highest on north-facing aspects, 5^{o} slopes and mid to upper slope positions. There was no consistent trend in downslope migration of soluble sodium, likely due to utilization of soil moisture by the forage crop. Upward migration of soluble sodium was similar to the subsoil depth experiment.

Status: The project is completed and a final report has been released: RRTAC 88-11. The cereal plots will be reseeded to forage and all plots will be maintained by TransAlta Utilities Corporation to allow for potential collection of data at a later date.

FIGURE 4c.
HIGHVALE SOIL RECONSTRUCTION PROJECT
SLOPE EXPERIMENT
LAYOUT
(NOT TO SCALE)

FORAGE CROP

2.5 WATER RELATIONS

2.5.1 Plains Hydrology and Reclamation Project - S.R. Moran, Alberta Research Council

This study examined the impacts of surface mining on the regional groundwater, geology and soils. The main objectives included the identification of:

1. changes in groundwater quality and quantity after mining;
2. sources and release rates of salts to groundwater;
3. changes in distribution of groundwater after mining (Will the groundwater carry salts to the surface? Will the watertable drop or will it re-establish at pre-mining levels?); and,
4. surface stability after mining (subsidence, piping).

Critical groundwater and geologic parameters were identified which allow us to predict the "reclaim-ability" of a site prior to mining. This project began in 1979 and was conducted in the Battle River and Highvale mining areas.

2.5.1.1 Phase 1. The first five years of the project (1979 to 1984) were devoted to:

1. Instrumentation to collect basic data on the geology, subsurface water, and soils of the Battle River mining area;
2. Mapping of the soil and geology of the area;
3. Analysis of properties of overburden materials, and, chemistry and movement of subsurface water;
4. Experimental studies on physical and chemical weathering of overburden materials;
5. Computer modelling of mine-affected groundwater flow systems;
6. Evaluation of hydrogeology and chemistry of minespoil at both the Highvale and Whitewood Mines;
7. Completion of infiltration tests in the spoil;
8. Development of a preliminary procedure to relate weathering data to groundwater chemistry in spoil; and,
9. Installation of field scale experiments at both sites to test the validity of the overall predictive framework on salt yield of the overburden.

The following represents a partial list of the conclusions from the first phase of the project:

1. Soluble salts already present in abundance in the overburden are sufficient to produce groundwater in spoil that has chemical quality substantially reduced relative to premining aquifers.
2. Weathering of overburden has very limited potential to substantially increase the salt reservoir within reclaimed landscapes.
3. There appears to be no justification for additional selective handling and placement of soil and overburden material over and above that currently practiced as a means to improve chemical quality of groundwater or to decrease potential for soil salinization.
4. There was no evidence of perching of water near the land surface, either within the subsoil or at the interface between the subsoil and spoil. (This conclusion has subsequently changed as a result of continued observations during Phase II.)

5. Discharge of spoil groundwater to surface streams should not result in measurable deterioration of chemical quality of receiving streams.
6. In some settings, discharge of spoil groundwater can significantly degrade chemical quality in shallow groundwater beneath unmined terrain adjacent to reclaimed areas at least 1.5 km from the mine boundary.
7. Mining will destroy all aquifers located above the base of the mine. Except in very rare cases, replacement aquifers cannot be re-established within the mine-spoil. In some areas of the Lower Horseshoe Canyon Coal Zone, alternative aquifers can be exploited beneath the base of mining.
8. Reconstructed soil landscapes are characterized by a higher degree of small-scale variability and lower degree of large-scale variability than are unmined soil landscapes.
9. The capability for agricultural production of reconstructed landscapes can be described and evaluated by a system that is essentially equivalent to that used in unmined landscapes.
10. Using the capability rating system that was developed by the project, it was determined that reconstructed soil capability was generally equivalent to the pre-mining soil capability. Post-mining capability reflects a more "average" capability as compared to the relatively higher and lower capability ratings attached to soil units in the premining landscape.

2.5.1.2 Phase II. The objectives of the second phase of the project (1984 to 1987) were reformulated from the objectives of Phase I to reflect the knowledge gaps identified in Phase I. The three subobjectives of this second phase focused on:

1. Design and construction of reclaimed landscapes that maximize long-term agricultural capability by minimizing potential salinization through the management of water in the landscape;
2. Assessing changes in agricultural capability and productivity of reclaimed landscapes on a long-term basis; and,
3. Refining our understanding of groundwater chemistry and recharge in reclaimed landscapes, as well as groundwater-induced salinization effects adjacent to reclaimed areas.

Work during 1984-85 focused on installation of intensive instrumentation in a number of slope and depressional settings in reclaimed and analogous unmined sites, primarily in the three mines at the Battle River site. Only preliminary data were accumulated from this new instrumentation.

During 1985-86 work focused on completion of instrumentation at field capillary study sites and along slope profiles in reclaimed settings, and at unmined reference slope sites. In addition, an experimental site to evaluate vertical salt migration above a shallow watertable in a simulated spoil profile was constructed. A second set of false-colour infrared photography was obtained, interpreted and ground checked as part of an analysis of techniques to identify distribution of soil salinity in reclaimed sites. A tracer study using bromide was conducted to assess the contribution to soil salinization by lateral flow in the unsaturated zone. Instrumentation of spoil subsidence

sites at Vesta and Paintearth Mines was completed. The other two major activities were monitoring of project instrumentation and continuing synthesis of results, and completion of Phase I reports.

In 1986-87, data collection continued, but the major activities focused on re-synthesis of models of infiltration and groundwater recharge, salt and water movement, and surface stability in reclaimed landscapes. The following is a partial list of conclusions arising out of Phase II of the project:

1. In well-drained landscape positions in reclaimed terrain, sodium is moving downward, suggesting that the quality of reconstructed soils in these settings is improving over time.
2. In well-drained landscape positions in reclaimed terrain, bulk density is decreasing with time. It appears that a significant portion of the decrease in density occurs in the initial five to seven years following reconstruction.
3. Saline conditions develop where the watertable is within about 1.0 to 1.2 m of the surface in the loamy, till-derived subsoil material that is typical of the Battle River mining area. In unmined settings in the same area, saline conditions have been observed where the watertable is as much as 2.0 m below the surface.
4. Strong upward capillary transport of water and salt is limited to a zone about 0.6 m above the watertable in the loamy, till-derived subsoil material that is typical of the Battle River mining area.
5. Depressions formed by differential subsidence in reclaimed landscapes contain ephemeral ponds that are potentially significant contributors to groundwater recharge during spring melt and heavy precipitation events.
6. Steady-state groundwater conditions are established in most sites in reclaimed landscapes within 10 to 15 years following mining where deep surface ponds are present and the spoil is 10 to 20 m thick.

Status: Phase II marks the completion of this major undertaking. The Alberta Research Council continues to conduct work under its own funding. Approximately 25 research reports are expected to be generated from this research project, including a summary report. Several reports have already been released: RRTAC 86-2, 86-3, 86-4, 86-5, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12.

2.5.2 Water Balance in Sodic Spoil - R. Johnson, Alberta Environmental Centre

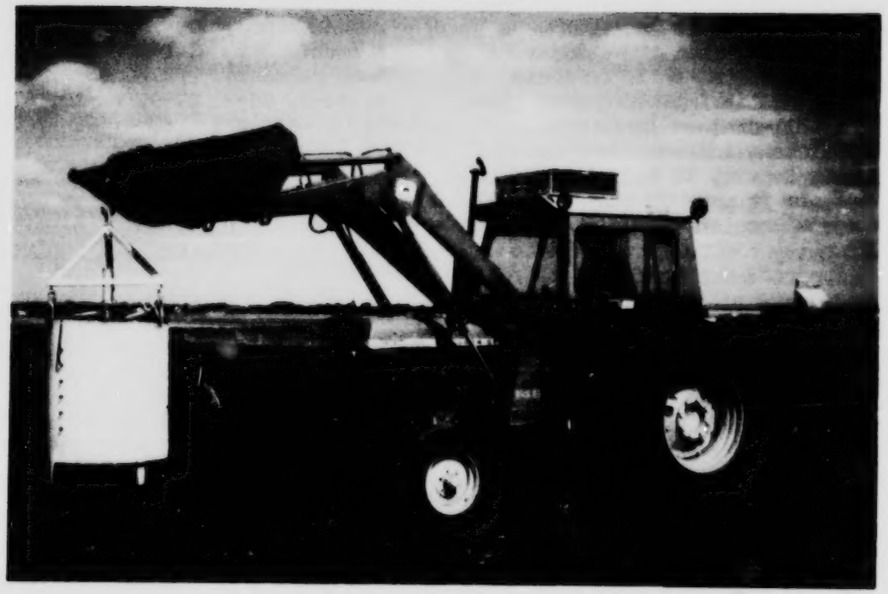
Work conducted by the Alberta Research Council in the previous project has shown that depth of the watertable in a saline sodic soil system can have a great effect on the quality of the rooting zone soil.

This study was initiated in 1986 to determine the effects of crop type, depth to groundwater and microclimate on salinity and water movement in reclaimed soils. Large lysimeters (75 cm wide x 100 cm deep) have been developed at the Alberta Environmental Centre (AEC) and will be planted to annual grain (barley or wheat), forage (alfalfa) or left fallow. One half of the lysimeters will have a watertable maintained at 95 cm, the others will be free draining.

The data collected will allow development of a model that can predict soil moisture content and

movement over large areas with few data inputs. This will allow land managers to predict optimum locations for crops on a reclaimed landscape and to predict the effects of those crops on soil water balance.

Status: The project is ongoing. More information is available in AEC annual reports.



3. MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

In 1984, The Coal Association of Canada and RRTAC agreed to jointly fund and manage the Mountains and Foothills Reclamation Research Program (MFRRP). The Program's focus is on Water Management, Soil Reconstruction, Reforestation and Wildlife Habitat Development.

3.1 RECLAMATION OBJECTIVES

1. Control of erosion on a variety of disturbances including coal mines, mineral exploration sites, and coal ash pits;
2. Return of forested lands to previous levels of capability; and,
3. Return of wildlife range to previous levels of capability.

3.2 THE PROBLEM

Reclamationists in the mountains and foothills face a wide variety of conditions. While some foothill sites are characterized by subdued terrain and moderate climate, other sites, particularly in the mountains, present steep slopes, rocky spoil and a short growing season. On these problem sites, summer droughts, chinook winds, erodible slopes and nutrient-poor soils are common.

On lower elevation foothill sites, reclamation is expected to yield forests with commercial potential while on the higher elevation mountain sites erosion control, and development of wildlife habitat and recreation potential are the reclamation objectives.

Reclaimed land in the mountains and foothills will not be as intensively managed as reclaimed agricultural lands would be. Also, topsoil and subsoil layers tend to be thin and difficult to handle selectively. Nonetheless, they are a valuable source of plant nutrients. So while some mixing of horizons is inevitable, how much is acceptable? How thick should the replaced soil layer be? Should the scarce topsoil be replaced evenly over the whole site, or in "islands" to provide a better growing medium in certain, designated areas? Other sites simply have no salvageable topsoil, and reclamation must prepare the site so that a plant-soil system will develop which will perform its land use expectations without indefinite fertilization.

3.3 RESEARCH APPROACH

There are four important aspects to reclamation in the mountains and foothills region:

1. The creation of stable reclaimable landscapes. This includes dump design (optimal slope, angles and lengths, terracing) and pit backfilling.
2. Preservation of watershed integrity and water quality. Water flow and sediment control are of prime interest.
3. Reconstruction of a suitable growing medium for each land use. The goal is to make the best use of limited materials to improve the rootzone over rocky, nutrient poor spoil.
4. Selection of suitable vegetation for each land use and proper planting to ensure survival and growth. The goal is creation of a self-sustaining cover that does not require long-term maintenance.

3.4 REVEGETATION

3.4.1 Selection of Native Grasses for Reclamation - R. Hermesh, Alberta Environmental Centre

Many alpine and subalpine sites are difficult to reclaim simply because commercially available grasses and legumes either cannot survive or cannot reproduce in the short growing season. This study has selected lines of native grasses which are known to invade disturbances in subalpine and alpine areas. Selections were made both on the basis of commercial potential and fitness of reclamation. The selected varieties are now in the process of being registered. They will be made commercially available and will be suitable for the reclamation of disturbances in Alberta's Eastern Slopes region.

Status: The project is ongoing. More information is available in AEC annual reports.

3.4.2 Growth Performance of Commercial Timber Species in Reclamation - W.R. Dempster and Associates Ltd.

The purpose of Phase I of this study was to review and report, from available literature, growth performance data that could be used to develop standards expected of commercial timber species for reclaimed lands in the Eastern Slopes of Alberta.

Phase II involved selection of a suitable growth performance measure and field data collection in the Eastern Slopes. Field work was undertaken on cut-over or burned sites during the summer of 1986 to acquire data on juvenile height development of commercial tree species growing in

coal-bearing areas of the Eastern Slopes of Alberta. These data were used to define reasonable expectations of early growth performance under prevailing environmental conditions, as a basis for evaluating the success of reforestation following coal mining.

Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures were described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth standards, and for testing actual growth performance against these expectations.

Data on the actual growth performance of seedlings on reclaimed sites were provided by three participating companies. The data were compared with the baseline models following as closely as possible the proposed procedures.

Generally, growth performance as measured by current or periodic annual increment was reasonably consistent with predicted values, especially when observed variability in the baseline data was taken into account. Total seedling height generally lagged well behind the predicted values. This observation appears related to early climatic and browsing damage, and initial planting shock. The fact that current increment is generally closer, and sometimes clearly exceeds, baseline predictions suggests that many seedlings have recovered from initial establishment problems. There seems to be little question that climatic factors exert an overriding effect on early stand growth, especially at higher elevations.

Status: The project is completed and a final report has been released: RRTAC 88-7.

3.5 WILDLIFE HABITAT

3.5.1 Reclamation for Wildlife Habitat in the Mountains and Foothills of Alberta: Phase I: Literature Review, and Phase II: Wildlife Habitat Certification Handbook - J.E. Green, LGL Ltd. (and later the Delta Environmental Management Group)

Mining developments in the mountains and foothills of Alberta inevitably result in the disruption of some wildlife habitat, either during site development or through clearing of linear rights-of-way (as during road construction or drill testing). Recent feasibility studies and several ongoing reclamation programs have shown that wildlife habitat can be created through reclamation and habitat enhancement, using existing technology applicable to the environmental conditions and wildlife species found in these regions. Although the capability currently exists to reclaim disturbed areas as wildlife habitat, no guidelines have been developed for evaluating success of wildlife habitat reclamation efforts. The development of guidelines for the reclamation of wildlife habitat was the primary objective of this study.

A two phase study on wildlife habitat reclamation began in 1984, with the aim of delineating appropriate operational techniques (Phase I) and assessment methodology (Phase II). Phase I of the program involved a synthesis of information on techniques relevant to wildlife habitat reclamation in the mountains and foothills biomes of Alberta, and a review of habitat requirements of key wildlife species in these regions. Following completion of the Phase I report, Environment Canada undertook

an expansion of the geographical scope of the technical synthesis to include the Boreal Forest, Aspen Parkland and Prairie Grassland regions. As part of this latter study, a techniques manual for the reclamation of wildlife habitat in Canadian prairie provinces was also developed.

Phase II of the program, begun in June 1986, involved the development of the assessment methodology for evaluating the success of wildlife habitat reclamation programs. Definitions of reclaimed habitat and guidelines for assessment will allow project proponents to define the objectives of their reclamation programs, to develop strategies to achieve these goals, and to identify and correct deficiencies prior to assessment. Proposed guidelines would also permit government regulatory agencies to consistently and fairly evaluate reclamation of wildlife habitat in different areas, and to identify inadequacies in habitat reclamation programs.

Results of the Phase II study were summarized in a technical report and an assessment handbook. The technical report provides background documentation for material contained in the handbook, including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques, and a glossary of basic terminology. The assessment handbook contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook was intended as a field manual that could potentially be used by site operators and reclamation officers.

Status: The project is completed. Two reports from the study have been released: RRTAC 86-3, 88-1.

4. OIL SANDS RECLAMATION RESEARCH PROGRAM

In order to pool resources and avoid duplication of effort, RRTAC and industry initiated a joint research program in 1979. Priority research areas included woody plants (propagation, establishment and management) and soil reconstruction. In 1986, the Program was expanded to include reclamation of tailings pond sludges.

Syncrude Canada Ltd. has been a very active supporter of this Program, providing research facilities and funds.

4.1 RECLAMATION OBJECTIVES

1. To develop techniques whereby a self-sustaining, erosion-free cover can be established on oil sand tailings pond dykes; and,
2. To return tailings sand storage and overburden dumps to productive forest.

4.2 THE PROBLEM

Northeast Alberta contains all of Canada's surface-mineable oil sands. Extraction of this valuable petroleum resource presents several problems for reclamation. By far, the greatest problem lies with the tailings disposal systems currently employed.

At the end of its 25-year life, a typical oil sand plant producing 19 900 cubic meters per day (125 000 barrels per day) of synthetic crude oil will require a 22 to 31 square kilometer (8.5 to 12 square mile) tailings pond. The liquid contents of the pond will consist primarily of 360 million cubic meters of sludge. The sludge will remain in a liquid state indefinitely and will be impounded behind dykes built of tailings sand. Dyke height will reach from 55 to 100 meters above ground level. Erosion protection will be provided by a cover of grasses, legumes and shrubs. Because the tailings sand is devoid of nutrients and drains rapidly, amending materials (muskeg, certain mineral overburdens) will be added to begin development of a soil.

Pits left after mining will be filled with tailings sand and overburden dumps will be constructed. These sites will also be reclaimed to a designated land use. Soil reconstruction and woody plant establishment in particular need further research.

4.3 RESEARCH APPROACH

As in the mountains and foothills, proper reclamation in Northeast Alberta will produce landform and plant community combinations which will fulfill their land use requirements without indefinite maintenance.

The approach to revegetation is to identify the best woody species to plant in reclamation areas and to identify the best soil amendments for tailings sand. Biological (plant species) and physical (slope, sand/sludge mixtures, freeze/thaw cycles) methods for dewatering tailings pond sludge are also being investigated. By dewatering sludge, a material with considerably less volume and with better engineering (trafficability) properties is created.

4.4 REVEGETATION

4.4.1 Oil Sands Soil Reconstruction Project - H.E. Martens, Hardy BBT Limited

Field trials were established on a 7 ha pad of tailings sand prepared

by Syncrude Canada Ltd. on their property north of Fort McMurray (Figure 5). Various mixtures of peat and clay were incorporated to 20 and 40 cm depths. In 1984, the plots were planted with tree and shrub species to identify the best soil prescription for a particular forest cover type. Data are being collected each year on tree/shrub survival, growth and spread, and on soil moisture and soil nutrients.

Status: The project is ongoing.

4.4.2 Mycorrhizal Potential in Reconstructed Soils - B. Danielson, University of Calgary

Mycorrhizal fungi nearly always enhance tree nutrition, and may therefore be an important factor in reclamation success, especially in nutrient poor tailings sand. The research concentrated on two pairs of species: jack pine and green alder which are mycorrhizal, and silverberry and buffalo-berry which are actinorhizal and nitrogen-fixing.

4.4.2.1 Mycorrhizal Plants. The overall objectives of the jack pine/green alder studies were to characterize the mycorrhizal status of these two species and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting. Much emphasis has been placed on gaining information on the fungi involved in the symbioses as little is known about the ecology of mycorrhizal fungi. This information is essential for successfully applying the technology.

Seedlings from seven nurseries in Alberta and British Columbia were examined for mycorrhizae. The conversion of short roots to mycorrhizae varied from 0 to 100% depen-

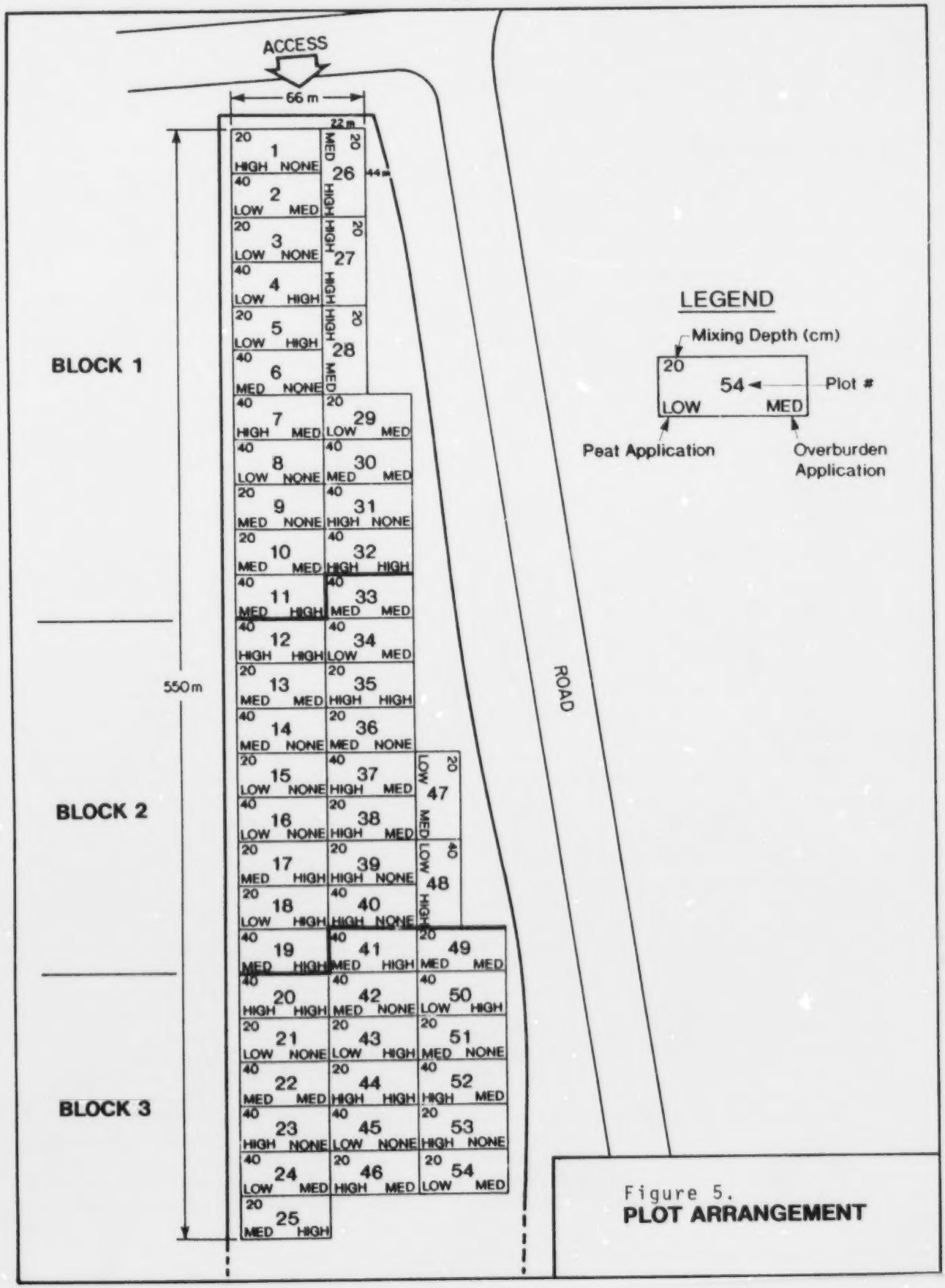


Figure 5.
PLOT ARRANGEMENT

ding upon the particular nursery, fertilizer regimes, and residence time in the nursery. It is without doubt that many sites are being planted with non-mycorrhizal jack pine, lodgepole pine, and white spruce. The most common fungi in the nurseries were E-strain, Thelephora terrestris and Mycelium radicis atrovirens. Amphinema byssoides occurred exclusively on spruce and succeeded E-strain and Thelephora in the nursery. Coltricia perennis, a polypore, was found on nursery stock for the first time. In one nursery, E-strain appeared to prevent the development of a seedling disease caused by a species of Cylindrocarpon. Alder seedlings from three nurseries were all non-mycorrhizal but most seedlings were nodulated.

The second major source of natural inoculum is the reconstructed soils and the inoculum source within the soils is the muskeg peat. Inoculum in undisturbed and stockpiled peat was assayed by using a greenhouse baiting technique and jack pine seedlings. The most common fungi were E-strain, I-type (Tuber sp.), and a hyaline Basidiomycete. Stockpiling the peat reduced the infectivity of the peat and plants were still mycorrhizal deficient after 4 months in the greenhouse. Additional experiments showed that the greenhouse baiting technique accurately reflected the species that develop in the field but over-estimated the rate of mycorrhization. The reconstructed soil contained adequate quantities of Frankia inoculum to nodulate alder but mycorrhizal inoculum compatible with alder was present only in very small quantities. From the nursery and indigenous inoculum studies it could be concluded that both jack pine and green alder planted on oil sand tailings amended with muskeg peat would potentially be deficient in mycorrhizae and this deficiency could adversely affect plant performance.

In order to determine if mycorrhizae would benefit plant performance in the field, two outplanting trials were conducted; the first with jack pine and the second with jack pine and green alder. The second trial was limited in scope due to heavy winter mortality soon after planting.

In the first trial, container-grown jack pine seedlings were inoculated with 12 fungi and mycorrhizae were formed by 9 of the 12 species. The most aggressive fungi (those producing the highest levels of short root infections) were Thelephora terrestris, Laccaria proxima, Hebeloma sp. and E-strain, all of which are known as "weedy" nursery species. A lower degree of infection was achieved with Cenococcum geophilum, Pisolithus tinctorius, Astraeus hygrometricus, Lactarius paradoxus, and Sphaerosporella brunnea. Amphinema byssoides, Hydnum imbricatum, and Tricholoma flavovirens failed to form any mycorrhizae. All the above inoculation treatments plus two uninoculated controls, one grown with the inoculated seedlings and the other from the Syncrude greenhouse, were outplanted in the spring on the Syncrude dyke. The reconstructed soil consisted of extracted oil sands, muskeg peat, and clayey overburden.

After one season in the field, T. terrestris, L. proxima, Hebeloma sp., and E-strain had all readily infected the new roots that extended into the reconstructed soil. The other fungi were poor colonizers of jack pine roots in the field. Competition from indigenous fungi was not a factor in the degree of success as only 4% of the short roots were infected by indigenous species. Growth of jack pine was not significantly affected by the presence of mycorrhizae during the first growing season.

Laccaria proxima completely disappeared after 1 year and between

the second and third year, Hebeloma sp. and Thelephora terrestris almost completely disappeared. Of the introduced fungi, only E-strain was present in substantial quantities after 3 years and it also appeared to be disappearing. It appeared that the major replacement process was noninteractive, i.e., the resident fungi died, and the roots were subsequently reinfected by another fungus. The colonization by indigenous fungi increased each year, rising to 33% in the second year and to 72% by the end of the third year. The most common indigenous fungi were E-strain, I-type (Tuber sp.), Mycelium radicis atrovirens, a Rhizopogon-like fungus, and a hyaline Basidiomycete. The latter four species increased with time, whereas E-strain appeared to be decreasing in abundance after 3 years. Shoot weights of seedlings inoculated with E-strain and Thelephora terrestris were 2- to 3-fold larger than the controls after 2 years growth but the differences in size decreased in the third year.

In the second outplanting study, inoculation could not be assessed due to heavy mortality but it was observed that three E-strain fungi and an I-type isolate all readily colonized new roots in the reconstructed soils. Alder lacked both nodules and mycorrhizae when planted but all plants became nodulated in the first year. However, mycorrhizal development was still often poor even after 2 years in the field. The major fungus associated with alder was Alpova diplophoeus which was also the dominant fungus on naturally regenerating plants.

In the jack pine outplanting study, fertilizer was used conservatively in the greenhouse phase so as to ensure maximum mycorrhizal development. Consequently, the seedlings were small and thus some losses were encountered in the field due to flooding of low areas of the experimental plot. Subsequent fertilizer trials have demonstrated that seedling size need not be sacrificed for successful mycorrhizal development when certain, aggressive fungi are used. The most fertilizer tolerant fungus tested was an E-strain isolate. All short roots were ectomycorrhizal when fertilizer containing 60 mg N L^{-1} was applied three times weekly. This rate approaches that used in commercial operations. Even when the rate was doubled, E-strain still infected a substantial portion of the short roots. Hebeloma sp. and Lactarius paradoxus were more sensitive to fertilizer levels, infecting 20 to 30% of the short roots at the 60 mg N L^{-1} level. Astraeus hygrometricus and Amphinema byssoides did not form ectomycorrhizae at this level, however this may have been due to an overall low inoculum potential of these two species. It is proposed that host resistance is elevated by high fertilizer levels and that it may be possible to overcome this resistance by increasing inoculum potential and thus, to expand the taxonomic spectrum of fungi that can be successfully introduced onto container-grown seedlings. A simple change from using an organic growing medium to an inorganic medium did not result in any ectomycorrhizal formation by two fungi which continue to resist artificial inoculation attempts, Amphinema byssoides and Suillus tomentosus. As these fungi appear to persist through several succession stages (multi-stage fungi), they may be more desirable than species currently being tested such as as E-strain, Laccaria proxima and Thelephora terrestris which are early-stage (pioneer) fungi.

One group of ectomycorrhizal fungi not included in any inoculation program are those species occurring in the late successional stages of a forest stand (late-stage fungi). At

this point, mycorrhizal infections of these species cannot be initiated from either spores or mycelium. However, at least some of these fungi can be very aggressive when spreading from established ectomycorrhizae to nonmycorrhizal seedlings. Nothing is known of the relative benefits on plant performance of these late-stage fungi versus the early-stage fungi whose use is currently in vogue.

It appears that multi- and late-stage fungi are more sensitive to certain biological soil factors than early-stage fungi. Preliminary attempts to reduce fungal antagonism by treating planting mixtures with the fungicide benomyl were unsuccessful. However, fly maggots, which were observed consuming inoculum, were eliminated by drenching the planting mixtures with Diazinon. By using intact cultures of fungi it was possible to increase inoculum potential and to observe consumption and colonization of the inoculum. Evidence from a series of trials indicated that if the antagonistic mold, Trichoderma harzianum and fungal feeding fly larvae can be controlled, it may be possible to inoculate many multi- and late-stage fungi and test efficiencies in the field.

Attempts to inoculate green alder with pure cultures of Frankia and Alpova diplophloeus failed; however, a soil inoculum was used successively to promote both nodulation and mycorrhization. It was necessary to reduce fertilizer levels to concentrations well below those used commercially to obtain mycorrhizal infections. Field-collected nodules also served as a good inoculum source for Frankia. Although antagonistic fungi and maggots could be controlled with pesticides, bacteria rapidly colonized inoculum of Alpova and killed the fungus. Further work is necessary to improve inoculation procedures so a wider range of fungi can be introduced onto ectomycorrhizal hosts and be subsequently tested for efficacy on reclamation sites.

4.4.2.2 Actinorhizal Plants. The ability of actinorhizal shrubs to tolerate inhospitable conditions while improving soil fertility and organic matter status has led to increased usage of these plants for land reclamation and amenity planting purposes. Silver-berry and buffalo-berry are two such shrubs which are being tested as potential candidates for the revegetation of the oil sands tailings in northeastern Alberta.

Associated with the roots of silver-berry and buffalo-berry are two symbionts - the N_2-fixing actinomycete, Frankia, and the vesicular-arbuscular mycorrhizal (VAM) fungi. Numerous studies have demonstrated that, particularly in nutrient limited conditions, mycorrhization and nodulation can result in significantly better plant performance as a consequence of improved N and P nutrition. The benefits conferred on the host by the symbionts may assume even greater importance in the revegetation of nutrient poor mine tailings.

In addition to reducing soil fertility, the upheaval and mixing of soil during the mining process can lower Frankia and VAM inoculum levels. Both soil fertility and symbiont inoculum potential can be improved by introducing an organic amendment to the minespoil. Soil reconstruction of oil sands tailings is facilitated by the application of muskeg peat. Alternatively, if woody plants are raised as containerized seedlings, they can be inoculated with both their N_2-fixing and mycorrhizal symbionts prior to being outplanted. However, before embarking on a large-scale inoculation program which will ultimately raise the cost of producing a seedling, factors such as plant depen-

dency on the symbionts, the level of Frankia and mycorrhizal inoculum in the outplanting soil, and the nodule/mycorrhizal status of containerized seedlings leaving commercial greenhouses should be considered. With this in mind, a research program was initiated to fulfill the following objectives:

1. To determine the mycorrhizal affinities of various actinorhizal shrubs in the Fort McMurray, Alberta region.
2. To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry. Factors investigated included: i) the dependency of the shrubs on their mycorrhizal and N_2-fixing symbionts as expressed in plant performance under inoculated and uninoculated conditions; ii) the Frankia and VAM inoculum levels in the outplanting soil including stockpiled peat on the Syncrude lease and soils reconstructed from peat, mineral soil and oil sand tailings; iii) rates of mycorrhization and nodulation in undisturbed and reconstructed tailings dyke soils; and iv) the mycorrhizal and nodule status of containerized shrubs raised in commercial and provincial nurseries.
3. To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry.
4. To conduct a field trial on reconstructed soil on the Syncrude site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their uninoculated counterparts.

The major findings on the justification of inoculation work were:

1. In Alberta, silver-berry and buffalo-berry are strictly VA-mycorrhizal. Levels of VAM colonization in roots of field collected plants can be as high as 60% suggesting a high degree of symbiont dependency under field conditions.
2. Silver-berry and buffalo-berry are highly dependent on their symbionts for optimum growth as evidence by four-fold (silver-berry) and nine-fold (buffalo-berry) increases in shoot weights when seedlings were inoculated with Frankia and VA-mycorrhizal fungi.
3. The VAM inoculum potential of both stockpiled and undisturbed muskeg peat is negligible due to the absence of VAM hosts.
4. Due to the low levels of VAM inoculum in the peat, stockpiling has no significant impact on VAM propagule levels. Vegetating peat stockpiles with VAM hosts such as grasses and legumes can increase VAM infectivity by 10 to 12% over six years. Tailings sand amended with peat would lack VA-mycorrhizal inoculum unless the peat had been vegetated with VAM hosts for a substantial length of time.
5. Soil from mixed woodlands (spruce, aspen, pine) had the highest VAM and Frankia inoculum potential of all soils assayed in the Fort McMurray area. Amending tailing sand with this type of soil would greatly improve symbiont infectivity.
6. Growth of slender wheatgrass in unfertilized, stockpiled peat is stimulated when inoculated with mycorrhizal fungi, suggesting VAM fungi are necessary to satisfy the nutritional demands of the plant when grown in P-deficient peat.

7. Containerized shrubs grown in various nurseries in Alberta and B.C. were seldom mycorrhizal and/or nodulated if less than one year old. Containerized shrubs which are more than one year old and have spent time in the shadehouse may or may not be colonized by their symbionts.
8. Buffalo-berry planted in reconstructed soil in the greenhouse did not become mycorrhizal or nodulated until eight weeks after planting. Since rates of colonization would be expected to be much slower in the field than in the greenhouse and since the growing season in the oil sands region is short, it is doubtful that containerized shrubs would obtain much benefit from the symbiosis during the first growing season unless artificially inoculated.
9. Uninoculated silver-berry seedlings outplanted on the Suncor dyke exhibited relatively rapid mycorrhization (within six weeks of planting) presumably due to high VAM inoculum levels resulting from the predominance of VAM hosts (grasses, legumes) on the dyke. In contrast, nodulation was poor, caused by either a lack of Frankia inoculum in the soil or poor root growth out of the planting plug.
10. The low VAM/Frankia inoculum potential and the slow rates of mycorrhization and nodulation in reconstructed soil on the tailings sand dykes, combined with the high dependency of silver-berry and buffalo-berry on their symbionts, forms a strong basis for artificial inoculation of containerized seedlings.

The major findings regarding the growing regime for producing mycorrhizal, nodulated plants were:

1. In order to produce mycorrhizal, nodulated silver-berry and buffalo-berry seedlings of suitable size and quality, fertilization should not exceed 56 mg N and 12 mg P per application. Fertilizer concentrations in excess of this do not totally eliminate symbiont colonization, but mycorrhizal and nodule development is severely reduced. The optimum fertilization regime in this study was 200 mg L^{-1} 28-14-14 Plant Prod Soilless Feed applied twice weekly.
2. Silver-berry growth was significantly better in 150 cc containers than in 65 cc containers. As soil volume was reduced there was a concomitant decrease in symbiont growth response so that inoculated seedlings in the 150 cc containers exhibited a significant growth response whereas those in 65 cc containers did not.
3. Seedlings inoculated with woodland soil demonstrated better mycorrhization and nodulation and a greater growth response at 26°C than at 16°C.
4. In a Frankia inoculum trial, the best sources of inoculum resulting in the biggest silver-berry seedlings with the most heavily nodulated root systems were found to be wild buffalo-berry soil, crushed silver-berry nodules, and crushed silver-berry nodules treated with polyvinyl pyrrolidine to reduce oxidation of phenols which inhibit Frankia growth. Seedlings inoculated with Frankia pure culture obtained from Rhizotec Labs in Quebec became heavily nodulated but this was not manifested in improved plant growth. Seedlings inoculated with a pure culture of Frankia isolated from buffalo-berry failed to become nodulated

possibly because the Frankia strain was incompatible with silver-berry.

5. Mixing a highly infective soil into the planting mixture appeared to be more effective at promoting symbiont development than applying the inoculum as a soil slurry after plant establishment.
6. Mycorrhizal, nodulated silver-berry and buffalo-berry of suitable size and quality were obtained by planting them in 150 cc containers filled with peat/vermiculite (1/1 v/v) which was supplemented with high inoculum soil (10 to 15% by volume), and fertilized twice weekly at a rate of 200 mg L^{-1} 28-14-14 Plant Prod Soilless Feed. Buffalo-berry appeared to be more N-demanding than silver-berry and may require a higher fertilizer concentration.

Status: The project is completed and two final reports have been published: RRTAC 88-3, 88-5. See RRTAC 84-4 for results of earlier studies.

4.5 OIL SANDS SLUDGE

4.5.1 Biological Dewatering of Oil Sands Tailings - R. Johnson and P. Layte, Alberta Environmental Centre

Five years of research at AEC and Fort McMurray have established three important facts about the dewatering of oil sands sludges (or fines less than 22 microns in diameter): (1) it is possible to dewater pure oil sands sludge (as opposed to mixing sand and sludge); (2) freezing and thawing sludge will cause the solids content to increase from 30% to 50% (dry weight basis); (3) reed canary grass can be established on sludge at 50% solids, and the plants will dewater the sludge so that a stable, competent surface results (approximately 80% solids).

Two of three objectives set for the project in 1987 have now been met:

1. The amount of dewatering of pure sludge that occurs as a result of freezing and thawing over winter has been established. Dewatering by freezing and thawing is dependent only on the initial solids content:

$$Y = 365.3\ (0.93)^X$$

where Y = solids content after freeze-thaw
X = initial solids content

(For further information see: Johnson, R.L., P. Bork and P. Layte. 1989. The effect of freezing and thawing on the dewatering of oil sands sludges. Paper to be presented at the 1989 International Symposium on Reclamation, A Global Perspective, sponsored by the Canadian Land Reclamation Association and the American Society for Surface Mining and Reclamation, Calgary, Alberta, August 27-31, 1989).

2. A surface drainage system for sludges has been constructed that is extremely simple, inexpensive and effective. Furthermore, it has been shown that surface drainage is absolutely essential; if the drainage system does not function properly and water is allowed to accumulate on the surface, originating from the thawing process or precipitation, plants will not establish and dewatering does not occur.

The third objective was to compare dewatering by plants (evapotranspiration) and by evaporation alone. Due to the malfunction of the first attempts at surface drainage, this comparison has not been made. It is obvious, however, that dewatering by plants is faster and much deeper when the plants are established in the early summer (late May in Fort McMurray).

Both pure sludge, starting at 30% solids, and sand-sludge mixes, starting at 50% solids, have been successfully dewatered using a combination of freezing and thawing, evaporation and evapotranspiration. The surfaces can now support the pressure of equipment traffic. Volume reduction as a result of dewatering varies according to the starting materials. For the pure sludges, the final volume is only 35 to 40% of the original; for the sand-sludges mixes, the final volume is 65% of the original. The difference is due, of course, to the different amount of water contained in the two materials initially and the water loss during freezing and thawing and evapotranspiration.

Reed canary grass has been shown to be hardy; it will overwinter in northeastern Alberta while growing on oil sands sludge.

The major problems to be addressed in 1989-90 are: (1) how to establish reed canary grass on pure sludge surfaces after freezing and thawing has occurred and (2) how to implement a surface drainage system after thawing on large scale (25m x 25m) dewatering ponds. In both cases the preliminary work shows that solutions are possible. Reed canary grass will start quickly from "sprigs" spread on the surface of the thawing sludge. And shallow trenches that act as drains can be easily installed in thawing sludge by pulling light weights over the surface.

Status: Work is ongoing. More details are available in AEC annual reports.

5. OIL AND GAS RECLAMATION RESEARCH PROGRAM

Conventional oil and gas deposits are found in all three biophysical regions noted above, while heavy oil deposits are found in the northeast. Since these disturbance types create similar reclamation concerns (disposal of drilling wastes, compaction, soil handling, residual herbicides) regardless of biophysical region, a separate program was developed to co-ordinate research.

5.1 RECLAMATION OBJECTIVES

1. To develop environmentally-safe methods for disposal of drilling wastes (fluids and solids); and,
2. To return land to a condition capable of sustaining an approved land use.

5.2 THE PROBLEM

5.2.1 Drilling Wastes

Three basic drilling muds and variations thereof are used for oil and gas exploration in Alberta. The freshwater gel bentonite is most commonly used followed by the salt water systems which use sodium or potassium. The oil invert drilling mud is also used and is gaining in popularity. Diammonium phosphate (DAP) mud is being used in the Cold Lake region.

The wastes produced from drilling operations contain many complex organic and inorganic compounds that are added at various stages of the drilling process. The materials that start out as drilling mud are usually extensively altered chemically and physically by the time they enter a waste pit. The muds can be altered by heat and pressure effects associated with drilling and by the addition of drill cuttings brought up with the mud system. The materials found in the waste pit can also be changed chemically and physically by other products that are purposely or inadvertently added to the pit. Caustic soda, rig wash, diesel fuel, waste oil from machinery, metal and plastic containers, and other refuse often find their way into a waste pit.

The physical location of the waste pits must be carefully chosen to minimize the potential for subsurface spread of leachates that may be generated from the drilling wastes. Knowledge of site characteristics such as: (1) the distance between the disposal site and the nearest surface water body, groundwater supply, or designated boundary, (2) the depth to the watertable, (3) the water table gradient away from the site, and (4) the type and thickness of geologic material through which the contaminated water could migrate is required to make decisions on the suitability of a waste pit location. Knowledge of proposed waste pit contents and their likely effects on the permeability of pit liners is also important.

Drilling wastes are currently disposed of by burying, trenching, squeezing, and spreading. Each of these disposal methods impacts the environment in different ways. For example, interactions of waste constituents with groundwater is much more likely to occur if wastes are trenched or buried as opposed to surface spread. The reverse is true for soils and plants.

Review of the literature indicates that effects of disposal of drilling wastes on plants and soils varies with the type of waste, rate of application and plant species.

A thorough physical and chemical analysis of the liquid and solid phases of wastes generated by drilling operations utilizing the different mud

types is one of the prerequisites to assessing the potential environmental hazard of the disposal of these wastes and developing environmentally safe disposal methods.

5.2.2 Compaction

Mining, pipelining and the construction of oil and gas leases all have dramatic effects on soil compaction. In fact, a recent report by the United States Office of Technology Assessment found that soil compaction was the single biggest problem in reclaiming cropland disturbed by mining. A survey conducted by the Pipeline and Wellsite subcommittee of RRTAC found that Reclamation Officers perceived soil compaction to be the prime concern in reclaiming oil and gas wellsites.

Repeated passage of heavy equipment during development and operating phases of a wellsite results in compaction of the soil. Compacted soil retards root development which can lead to moisture and nutrient stress in plants. This, in turn, retards shoot development and yield. Freeze/thaw and wetting/drying cycles were thought to loosen compacted soil, but current evidence suggests that their benefits are rather limited. In Alberta, moderately compacted soils can have recovery times measured in decades; high clay contents are associated with long recovery times.

There is a paucity of useful data pertaining to soil compaction in Alberta (and elsewhere), largely because a fully satisfactory measurement has yet to be identified. Crop yield is the best measure of compaction in addressing agricultural concerns. However, the effect of soil compaction on crop yield varies with soil type, yearly meteorological conditions, and type of crop. A measurement of compaction must be identified that has a high correlation with plant response, is independent of soil type, is inexpensive, and can be performed rapidly.

Bulk density is most commonly used to determine soil compaction but shows considerable natural variation due to soil particle size distribution and organic water content, and has no unique value at which root growth is impeded. Hydraulic conductivity, porosity, air permeability, infiltration and sorptivity yield valuable information about the effect of compaction on physical processes in soils. But these measurements are not used widely due to long measurement times, wide data variability, departure from normality and the absence of an exact relationship between these properties and plant growth.

A hand penetrometer, developed at the Alberta Environmental Centre, allows mechanical impedance to be measured at various depths in the field at extremely low cost. Now, Reclamation Officers are equipped to measure compaction at any disturbed site. However, there is little information relating mechanical impedance or any other measurement to reductions in crop yield in Alberta. What is needed is a simple model for routine applications that predicts plant yield with a minimum of data input.

It is important to note that while wellsites were chosen for evaluation of compaction problems, any disturbance that involves the use of heavy equipment can produce compaction. Thus, the results of this research may be applicable to pipelines, highways, mines, sand and gravel pits, and forestry skid trails and loading zones, among others.

5.2.3 Residual Herbicides

Soil sterilants, residual herbicides that render the treated soil unfit for plant growth for relatively long periods of time, are used in Alberta on wellsites, rights-of-way and other industrial areas for total vegetation control. Such vegetation control measures reduce fire hazards and improve aesthetic appearance. The treated areas can remain devoid of vegetation for many years depending upon the type and rate of soil sterilant used and the soil and climatic conditions. Furthermore, it is not uncommon to use more than the recommended rates of these chemicals for achieving long-term vegetation control with a single application. Bromacil and tebuthiuron are the commonly used soil sterilants in Alberta.

Once the sterilant-treated site is abandoned, it may take several years before the site is restored to its original capability. The site also becomes a potential source of contamination through surface runoff and wind dispersion of soil sterilants onto adjoining untreated land. In Alberta, the extent of the soil sterilant problem is becoming apparent as more oil and gas lease sites are abandoned due to the marginal production value of many wells. The seriousness of the problem has been identified by various provincial organizations and committees.

5.3 RESEARCH APPROACH

In 1984, RRTAC sponsored a two-day workshop on drilling waste disposal in Alberta (RRTAC 87-3). The workshop identified a number of concerns that needed to be addressed.

As a result of this workshop, initial research focussed on trying to develop a manual that could be used by field staff to determine whether a waste could be safely spread on a given soil surface. The manual pointed to a need for detailed chemical characterization of sump fluids and solids before rational disposal decisions could be made. Thus, Phase I of the program has concentrated on getting chemical data from various drilling mud types in various regions of the province.

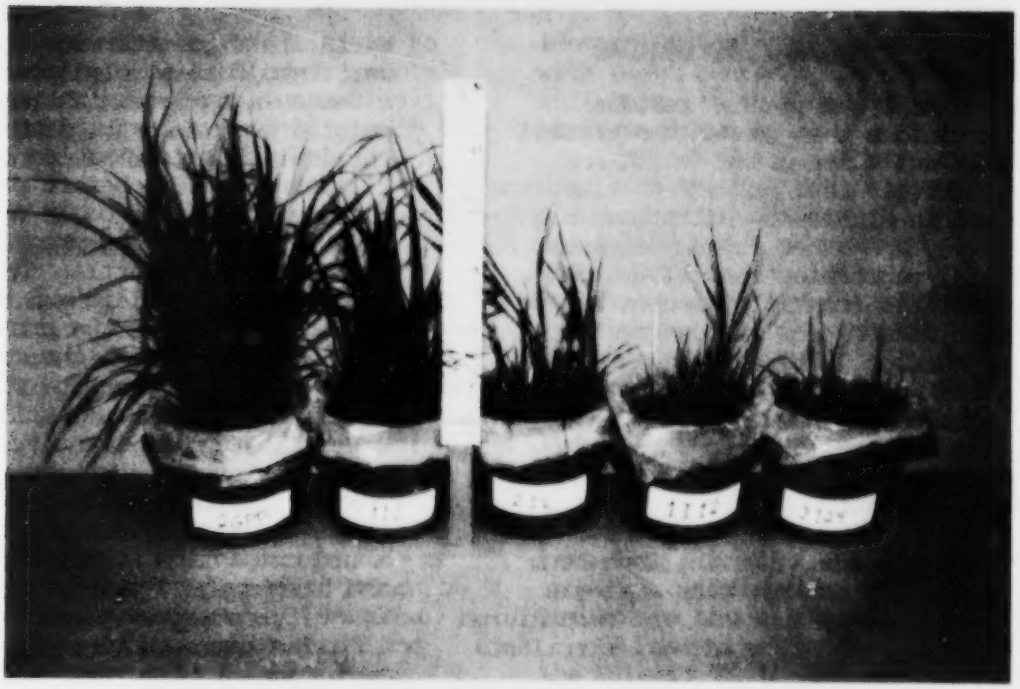
The approach to the compaction problem was to determine what characteristics predispose a soil to compaction and to identify the best field method for identifying and quantifying compaction. This knowledge will allow operators to avoid compaction wherever possible, and allow regulatory personnel to identify compacted areas.

The approach to the residual herbicide problem was to identify methods for binding the herbicide, thus rendering it ineffective.

5.4 DRILLING WASTES

5.4.1 Drilling Mud Disposal - T. Macyk, Alberta Research Council

The purpose of this project is to provide a scientific basis for development of guidelines for drilling mud solids disposal that optimizes environmental safety and cost effectiveness by carrying out problem analysis, and preliminary research to identify environmental limitations of available disposal technology. Drilling waste fluids and solids were collected from sumps at wellsites in Cold Lake (1986/87) using KCl, NaCl and freshwater muds, and the Eastern Slopes in 1987/88. Samples from the Peace River/Grande Prairie region were collected in 1988/89. Samples were collected at several depths and in several locations within a sump to



determine spatial variability in chemistry. A suite of chemical analyses was performed to characterize both solids and fluids. Samples of sump solids were mixed at various rates with a soil indigenous to the region and planted to a grass species typically used in reclamation. The results of this test will provide preliminary indications of how much waste can be added to soil and still achieve acceptable reclamation.

In addition to the field study, a literature review was conducted to assess the effectiveness of geological containment of drilling waste in sumps. Three premises were identified at the outset of the study. The first was that disposal of drilling waste in sumps is likely to be a standard practice in parts of Alberta. Secondly, heavy-duty polyethylene liners and exotic clay materials are too expensive for use in most drilling-waste disposal sumps, and finally that compacted indigenous clay liners will be used in most waste sumps.

A literature review was conducted in sources identified through a search of the GEOREF and NTIS data bases involving two combinations of keywords in each data base. One hundred and eleven references were identified for the period 1985-1987. Two particularly useful publications that were reviewed were, "Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities", a comprehensive report prepared for the US Environmental Protection Agency, and "An Evaluation of the Effects of Brine on a Compacted Clay Till Liner", a report prepared for Alberta Environment. The Geotechnical Research Centre of the University of Western Ontario, which is internationally recognized for its expertise in contaminant transport studies in clayey materials, provided

a number of additional reports based on current research.

The review indicated that glacial till throughout Alberta has similar properties and is generally well suited for construction of clay liners. Optimum liner characteristics of low initial permeability and low shrinkage are obtained with materials containing appreciable sand and by compacting at slightly above optimum water content. At the expected hydraulic conductivity of liners constructed of Alberta till materials, advective transport is expected to dominate over diffusion.

For the purpose of assessing hydraulic conductivity, a constant-flow type permeameter appears to be the best testing apparatus for laboratory determination of hydraulic conductivity. No definitive explanation has been advanced for the almost universally observed one to two order of magnitude difference between field and laboratory determinations of hydraulic conductivity of compacted clay liners.

Smectitic clays, such as are common in Alberta, experience an increase in permeability in contact with hypersaline and organic permeants. Laboratory studies of smectitic clays in solutions containing high concentrations of potassium ion have demonstrated severe shrinkage. Field studies of interactions between hypersaline fluids and clay liners have focused on sodium; no field studies of permeability characteristics of liners exposed to high concentrations of potassium ion were documented in the literature.

Organic permeants with low-dielectric constants tend to increase permeability by inducing shrinkage, but commonly give misleading or erroneous results in laboratory tests because of their hydrophobic nature and low solubility in water. Attenuation of sodium, potassium, total dissolved solids, total organic carbon, and heavy metals, although difficult to quantify, appears to increase with increasing cation exchange capacity of the liner.

Classification of clay liner characteristics and waste composition should precede design of individual facilities because interactions between the two are not straightforward.

It is recommended by the authors of the report that a scientific study be conducted to investigate the chemical and structural factors in construction and performance of clay liners composed of Alberta till. The study should further evaluate the effects of interactions of the various chemical constituents of drilling wastes with the liner material on the long-term permeability of the clay liners.

In addition, an expert system should be developed to access the exhaustive body of knowledge on the interactions between different types of clay liners and various specific permeants to allow prediction of the behaviour of a particular clay with a particular suite of drilling-waste constituents. Such a system would allow assessment of environmental sensitivity of a proposed sump site, optimum liner design, and assignment of quality control during construction.

It is also recommended that guidelines for construction of clay liners for drilling-waste disposal sumps should specify acceptable confidence limits within which parameters such as compaction water content, dry density, material variability, and hydraulic conductivity are allowed to vary, rather than identifying specific values for these parameters.

Status: Project is completed. A report on the clay liners has been published: RRTAC 88-10. A summary report for the three year field study is being reviewed.

5.5 COMPACTION

5.5.1 Compaction on Oil and Gas Leases (Phase I) - N. Finlayson, Can-Ag Enterprises Ltd.

The concern in compaction-related reclamation research is measuring variables which can influence root development below the cultivated zone and evaluating whether or not these variables are substantially different from those in nearby non-compacted soils.

Bulk density is most commonly used to determine soil compaction, but it shows considerable natural variation due to soil particle size distribution and organic matter content, and has no unique value at which root growth is impeded. Hydraulic conductivity, porosity, air permeability, infiltration and sorptivity yield more valuable information; however, they are restricted from widespread use due to the considerable measurement time involved, the wide data variability, departure from normality, and the absence of an exact relationship between these properties and plant growth.

Investigation of the relationship between soil mechanical strength, as measured by penetration resistance and plant root growth, indicates that a rapid, inexpensive measure of compaction may be available. Although soil strength is dependent on moisture content, texture, and soil fabric, the unambiguous relationship between soil strength, regardless of its cause, and root growth makes mechanical impedance

a potentially valuable measurement of soil compaction.

Cone penetrometers are widely used for studies of soil trafficability and are now commonly used to measure soil compaction. The cone penetrometer has even been adopted by some for routine use in evaluating compaction problems in land reclamation. Perhaps slowing a more widespread use of penetrometers is a standardization problem. Penetrometer cones come in various shapes and sizes with results depending to some degree on the type of cone used. However, quantitative results from penetrometer cones of the same type produce consistent and comparable results. Penetrometer readings should be made at some standard soil moisture, preferably field capacity which would identify the strength of least resistance to root growth. In this regard, readings taken in spring, late fall, or after heavy rainfall may prove most valuable, although readings under drier conditions may have equal merit if reasonable caution is exercised.

This field survey project addressed four compaction concerns on east central Alberta oil and gas wellsites:

1. The suitability of various methods of measuring compaction (soil strength, bulk density, morphology, porosity, pore size distribution) with regard to their sensitivity in detecting compaction, the number of samples necessary to adequately assess compaction, the time and cost involved, and the skill, equipment or facilities necessary to use the technique;
2. The extent of soil compaction, both vertically and horizontally;
3. The degree of soil compaction on oil and gas well lease sites as compared to adjacent off-site areas; and,

4. The nature of soil compaction with respect to how various soil properties are affected by the compaction process.

To accomplish these goals, a two-stage survey was conducted. A detailed survey concentrated on establishing appropriate sampling densities and on evaluating various techniques of measuring compaction. At five wellsites, data were collected on soil strength (recording penetrometer), undisturbed cores were collected for measurement of bulk density and pore size distribution, disturbed or undisturbed cores were collected for measurement of moisture content, texture and organic matter, and soil profiles (for classification) and soil morphology (for the morphological compaction classification technique of McKeague et al.) were recorded.

The second part of the survey involved an assessment of soil compaction on 20 wellsites using a recording penetrometer to measure vertical and horizontal soil compaction profiles. Emphasis was placed on strength measurements because they can be taken quickly, no expensive and time consuming laboratory work is required, and work at the Alberta Environmental Centre and elsewhere suggests that soil strength may be the variable most closely related to plant growth in compacted soils.

The information generated by this research should better determine the nature and scope of the compaction problem and will establish appropriate methods and sampling designs for future work concerning compaction on Alberta oil and gas leases.

Status: This phase of the compaction work is completed and a final report is in preparation.

5.5.2 Compaction on Oil and Gas Leases (Phase II) - R. Johnson, Alberta Environmental Centre

The main objective of this research is to identify the relationship between subsoil compaction, topsoil depth and plant productivity under a range of conditions (soils and years). The experiment is factorial and arranged in a completely randomized design, with three compaction levels (no compaction, medium, and heavy compaction) and four topsoil levels (5, 20, 35, and 50 cm depth). Each treatment is replicated four times at each of two sites (a Chernozem soil in Vegreville - Figure 6, and a Luvisol near Myrnam - Figure 7) for a total of 96 plots. Barley will be grown in each plot for three years, and the growth response (measured by root biomass, root length, shoot biomass and crop yield) will be related to three measures of soil compaction (penetration resistance, bulk density and porosity). The null hypotheses are:

1. The degree of subsoil compaction does not influence barley growth or productivity (as measured by yield, biomass, or rooting characteristics) in fine-textured soils.
2. Barley growth and productivity on compacted, fine-textured soils is independent of topsoil depth.
3. The relationship between barley growth and productivity, and subsoil compaction is independent of soil type (Chernozem or Luvisol).
4. Barley growth and productivity on compacted, fine-textured soils is independent of climate (year).
5. There are no interactions between subsoil compaction, topsoil depth and climate (year) that influence

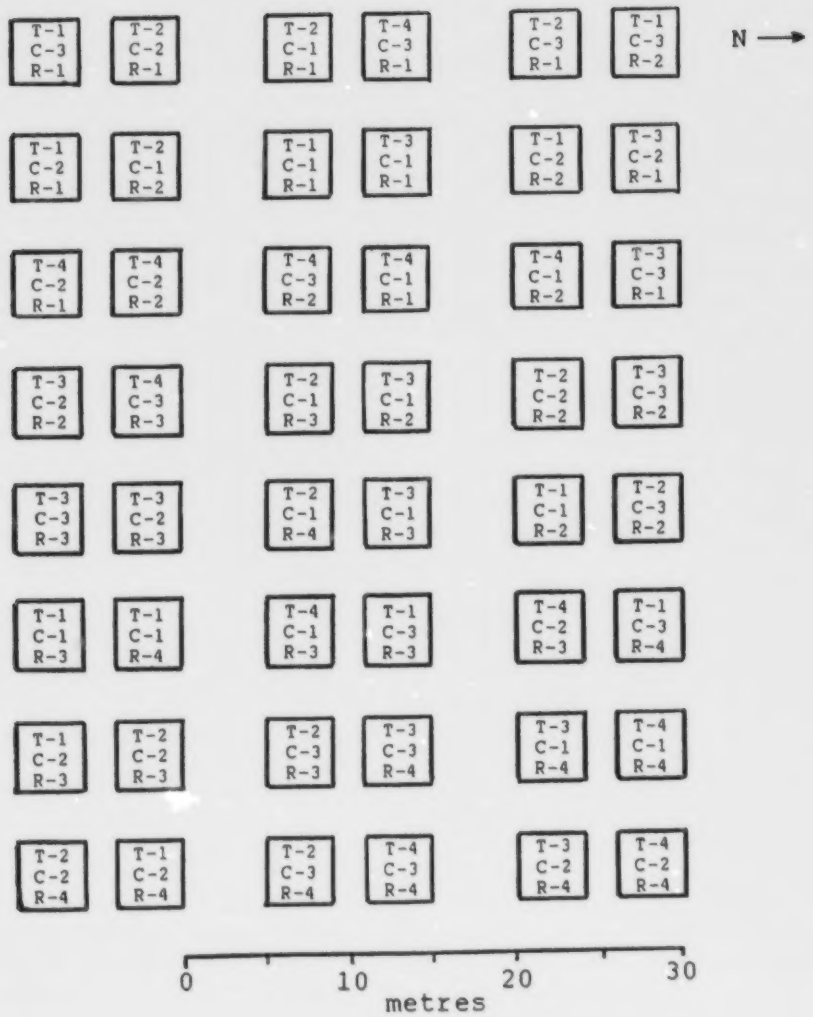


Figure 6. Compaction plot layout at the Chernozemic site, located near Vegreville, Alberta. T indicates topsoil depth, where 1 = 5 cm, 2 = 20 cm, 3 = 35 cm, 4 = 50 cm. C indicates compaction level, where 1 = no compaction, 2 = moderate compaction, 3 = heavy compaction. R indicates replicate number.

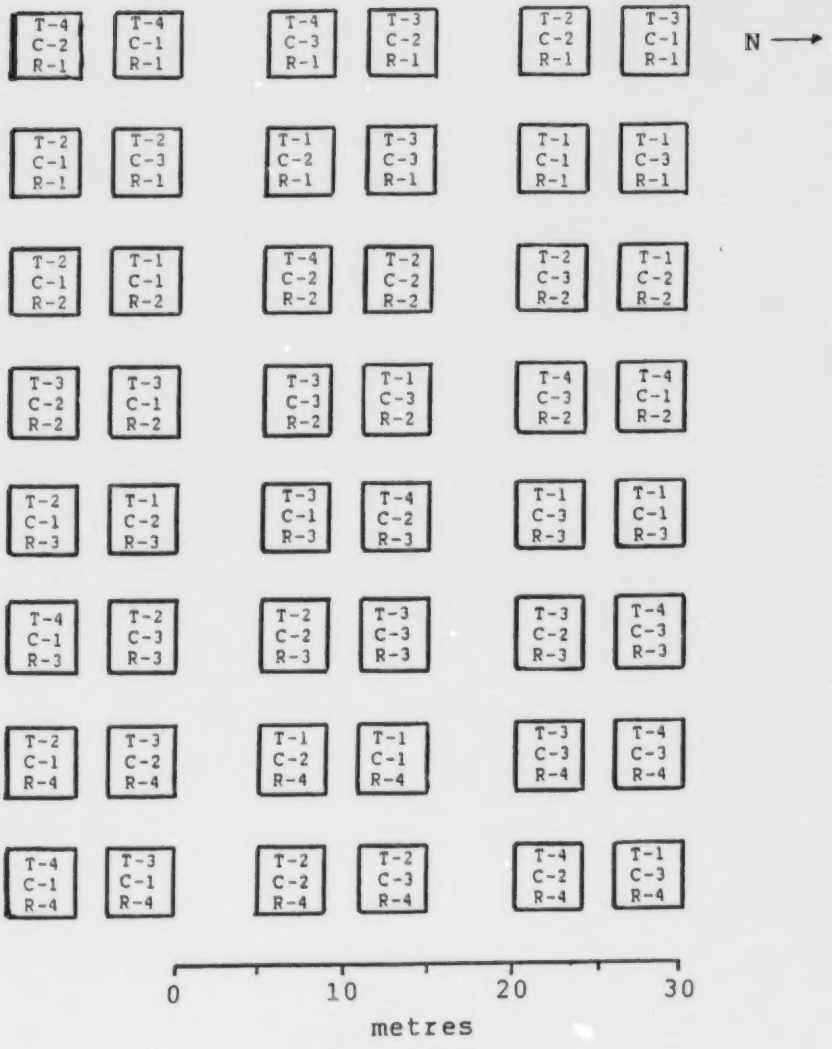


Figure 7. Compaction plot layout at the Luvisolic site, located near Myrnam, Alberta. T indicates topsoil depth, where 1 = 5 cm, 2 = 20 cm, 3 = 35 cm, 4 = 50 cm. C indicates compaction level, where 1 = no compaction, 2 = moderate compaction, 3 = heavy compaction. R indicates replicate number.

barley growth or productivity on compacted, fine-textured soils.

6. Soil strength, bulk density and pore-size distribution are equally accurate in predicting barley growth and productivity in compacted, fine-textured soils.

Plots are adjusted to three levels of subsoil compaction to encompass a range consistent with that measured on wellsites in northeastern Alberta. The lowest strength (control) is selected as the lowest compaction level that will not settle and become more compact over the three year duration of the experiment. The most compacted level was chosen to be similar to that on compacted wellsites and found to be limiting to root growth even under field capacity moisture conditions. A 30 cm thick layer of compacted subsoil is used in each plot; 30 cm thick compacted layers have been documented on wellsites in Alberta, and heavy agricultural traffic is capable of compacting soils to more than twice this depth.

For each subsoil compaction level, four depths of topsoil cover are used: 5 cm, 20 cm, 35 cm, and 50 cm. These depths provide a range of conditions: from too little soil to support a crop, even under ideal moisture and nutrient conditions, if subsoil compaction is severe; to sufficient topsoil to support a full crop, regardless of subsoil compaction, under all but the most limiting moisture conditions. The minimum depth is chosen to ensure seedling establishment; the maximum depth is an upper limit of topsoil available for reclamation under any conditions.

Barley has been selected as the test crop based on its widespread cultivation in Alberta, its high salt tolerance (preventing any salt effect from becoming the limiting factor to plant growth) and its use as a monoculture on small plot areas for several years without significant problems. Additional species would undoubtedly provide additional information but would result in a prohibitively large experiment.

Each plot is 4 m x 4 m such that the total plot area at each site, including walkways and machinery access, encompasses about 0.25 ha with approximately 0.1 ha of cropped area. A 0.5 m margin around each of the plots will be excluded due to border effects, so that the actual sampling area of each plot will be 3 m x 3 m.

Soil strength to the base of the compacted layer will be monitored weekly by using a Centre Cone Penetrometer. This instrument is capable of measuring soil strength up to 110 bars, about four times higher than the point at which root growth ceases, and can be fitted with specially-designed rods to permit strength readings to 80 cm depth. Changes in penetration resistance will reflect changes in soil moisture. Soil cores will be used for monitoring rooting characteristics (once per month) and changes in bulk density and pore size distribution (at the end of the experiment). Grain yield and shoot biomass will be measured at the end of each of three growing seasons. Soil fertility will be measured in the plots and adjusted to a common level each year.

It is anticipated that three years of data will be sufficient to analyze plant response under different growing season conditions. If this time period proves to be insufficient, the study may be extended.

Status: The project is ongoing. More information is available from the Alberta Environmental Centre.

5.6 STERILANTS

5.6.1 Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil - Mr. E. Hemminger

A greenhouse study was conducted to investigate the efficiency of activated charcoal for inactivation of bromacil and tebuthiuron residues in soil as influenced by factors such as herbicide:activated charcoal ratio, soil texture, organic matter content, soil moisture, and the time interval between activated charcoal incorporation and plant establishment. Oat (Avena factus L.) was used as a bioassay species to assess the phytotoxicity of bromacil and tebuthiuron residues. Both herbicides were more phytotoxic when applied to sand or a mixture of sand + soil (1:1, w/w) as compared to a sandy clay loam soil.

Activated charcoal at rates up to 400 ppm in sand, soil or the sand + soil mixture was not phytotoxic when incorporated without the herbicides. Incorporation of activated charcoal at rates ranging from 100 to 400 times the herbicide active ingredients (0.2, 0.8, and 2.0 ppm) protected oats, to varying degrees, from bromacil and tebuthiuron injury. The level of protection varied with the ratio of herbicide to activated charcoal and soil characteristics, mainly the organic matter and clay content. In general, nearly complete protection was achieved when the herbicide to activated charcoal ratio was 1:200 or more.

Protection of oats from bromacil or tebuthiuron injury improved as the time interval between activated charcoal incorporation and the seeding of oats increased from 0 to 1, 2 or 4, and 6 weeks. A time interval of at least one week was required for optimum binding of bromacil or tebuthiuron residues in soil by activated charcoal applied at a ratio of 1:100 (herbicide:activated charcoal). A shorter interval was required at a ratio of 1:400.

Injury to oat plants from bromacil or tebuthiuron decreased as the soil moisture level decreased. Protection of oat plants from herbicide injury by activated charcoal, especially at lower herbicide: activated charcoal ratios, was slightly better under the lower moisture regimes than at the high moisture regime. This difference was considered due to an increased activity of bromacil and tebuthiuron under optimum moisture conditions rather than a direct effect of low moisture regimes on the efficiency of activated charcoal on herbicide inactivation.

Results of this greenhouse study showed that activated charcoal, at ratios of 1:200 or more (herbicide active ingredient:activated charcoal), can be effectively used to inactivate bromacil and tebuthiuron residues in soil. The efficiency of treatment depends on activated charcoal ratios, soil characteristics (texture, organic matter content and moisture level) and the time interval between activated charcoal incorporation and plant establishment.

Status: Project is finished. The final report is being prepared.

6. GENERAL PROGRAM

The projects listed under the General Program have application to all the RRTAC Programs and, in some cases, to other disturbances types not studied by RRTAC. These projects are selected and managed by RRTAC rather than by a specific Program Committee.

6.1 PROGRAM DEVELOPMENT

6.1.1 Future Research Needs - J. Smith, Concord Scientific Corporation

RRTAC has provided funding for reclamation research in Alberta for eleven years and is now evaluating future directions for the research program. Concord Scientific Corporation and RRTAC designed a questionnaire to determine the reclamation research needs of organizations/industries in Alberta involved with industrial disturbances. The results of this study will help RRTAC to recommend the direction to be taken in funding research programs over the next five years.

A list of organizations involved with reclamation in Alberta was developed with the assistance of RRTAC. This mailing list included members of industry, consultants, and the provincial and federal governments.

In the detailed questionnaire the following information was requested for each research need identified: the geographic location, type of disturbance, end land-use, and codes to describe the research. Each respondent was asked to list up to ten research areas and to prioritize them from most to least important, with priority ranking 1 representing the most important research need and priority ranking 10 representing the least important of the ten research needs.

The questionnaire was pre-tested with three participants who work in the reclamation field: Al Fedkenhueur of NOVA Corporation of Alberta, Phil Lulman of TransAlta Utilities Corporation, and Dean Mutrie of Tera Environmental Consultants. The participants were asked to review the questionnaire for the following aspects: completeness of the questionnaire in covering relevant topics, clarity and readability of instructions and code options, and format and ease of use of the questionnaire. The participants were interviewed and the questionnaires were modified based on their recommendations.

A total of 221 questionnaires were mailed. The approximate distribution of the questionnaire by organization/industry affiliation was 51% sent to government, 37% to industry and 12% to consultants. A total of 119 responses were received; 47% from government, 36% from industry, and 17% from consultants. Some respondents provided fewer than 10 research needs, while others provided more. In all, 1214 needs were identified.

From this set, a list of the top 10 needs was prepared based on frequency of response (i.e., the most common needs) and priority (i.e., the most important needs). These top 10 needs will be used in a general sense to help identify program priorities.

However, to identify priorities within programs, the original list of needs was further analyzed by disturbance type and geographic location, and relevant topics placed into the four current RRTAC Program areas. The Oil and Gas Program had the greatest number of needs identified, followed by the Mountains and Foothills Program; the Oil Sand Program and the Plains Coal Program had a similar number of needs identified. The top

10 needs in each program were then identified using a similar frequency/priority analysis.

Status: The project is completed and a final report is in progress.

6.2 VEGETATION

6.2.1 Update of Plant Species Suitability Manual - H. Martens, Hardy BBT Limited

In 1980 RRTAC published report 80-5: Manual of Plant Species Suitability for Reclamation in Alberta, to provide users with information on a variety of plant species suitable for use in reclamation programs in Alberta. The manual was well received by reclamation specialists, plant biologists, ecologists, and the general public, and has recently gone out of print.

Since 1980, new information on the species in the manual has been produced through operational and research activities. In addition, new species and/or varieties have been tested in Alberta. All of this new information needed to be incorporated into an updated manual so that reclamation specialists and other persons interested in vegetation have access to the best information available.

The detailed information (including data and references) from the existing manual and update will be described under the following headings to facilitate information retrieval:

1. Species biology (taxonomy, distribution, propagation, etc.).
2. Tolerances (drought, cold, salt, acid, etc.).
3. Reclamation considerations (seed availability, methods of establishment, current use, etc.).

The existing natural vegetation in the province provides a broad indication of growing conditions and is a useful tool in selecting species for reclamation. The development of the ecoregion map of Alberta by Strong and Leggat adds more information on regional soil and climate, and will provide an informative and standard base on which to indicate where a species is most suited. The ecoregion map will be modified to suit the purpose and scale of the manual.

The criteria for selection of a species for a particular reclamation site will be prioritized. This information is currently in the manual, however it is not readily accessible.

The emphasis in the update of the manual will be to add recent Alberta-specific information to the species already listed. However, if new and promising species are identified these will be added. Only species with high potential for use in Alberta will be selected for addition in the manual.

A major objective in the update of the manual will be to add recent (since 1980) Alberta-specific information gained through monitoring of research plots and reclamation sites throughout the province. This information would be integrated under the existing headings. Where available, information on years of testing and site location will be included, building confidence in the suitability of a particular selection for particular site conditions.

Particular emphasis will be placed on gathering information on tolerance to hydrocarbons and trace elements as well as sulphur. The need is increasing for reclamation of industrial sites contaminated with hydrocarbons, (i.e., wellsites), or subject to sulphur dioxide fumigation, (i.e., oil sands region, mines near coal-fired hydro-generation plants,

gas plants, etc.). In situations such as those just mentioned, tolerance to these parameters becomes a major selection criteria. New information on these parameters will be added and deficiencies will be noted.

The major source of update information will be annual reclamation monitoring reports submitted to the government for mines, pipelines, gravel operations, and other industrial sites throughout the province. Research plot work at the Alberta Environmental Centre will be reviewed as well as applicable RRTAC studies including both field trials and literature reviews. With regard to the latter, RRTAC report 82-1: Land Surface Reclamation: A Review of the International Literature is a valuable source of information. Although most of the literature cited in this report is pre-1980, many of the papers are not referenced in the previous species suitability manual.

In addition, funding from the Recreation, Parks and Wildlife Foundation will allow inclusion of line drawings of each species. This will help make the manual more useful in the field for both specialists and the general public.

Status: The project is ongoing.

7. PREVIOUS RESEARCH

7.1 PLAINS COAL RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Agricultural Capability

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Groundwater/ Geology	- Effects of mining on groundwater supplies - Generation of salts in spoil - Transport of salts near the reclaimed soil surface - Subsidence after reclamation - Overburden classification	The regions including and surrounding the Battle River and Highvale Mining areas have been intensively monitored to assess the effects of mining on the soil, water and ultimately, the agricultural resources. The hydrology project is completed The long-term effects of subsidence, salinization and soil quality are being monitored by ARC. See RRTAC Reports 80-3, 86-2, 86-3, 86-4, 86-5, 86-6, 86-7, 87-9, 87-10, 87-11, 87-12, 87-13, 88-2, 88-4, 88-9, 88-12.
Soil Reconstruction	- Thickness of subsoil required above sodic spoil - Effects of slope on lateral salt transport - Reconstruction of Solonetzic soils - Use of bottom ash as a soil amendment - Effects of crop type - Changes in topsoil during stockpiling	Experimental plots have been constructed on the Battle River and Highvale Mine areas and 1988 will be their seventh and sixth crop years, respectively. See RRTAC Report 88-11. An experiment to test optimum amounts of bottom ash and incorporation methods has been completed. See RRTAC Report 87-7.
Fly and Bottom Ash Disposal	- Chemical and physical properties of Alberta fly and bottom ashes - Potential for use as soil amendment	Ashes from five Alberta sources were analyzed for both toxicity and soil amendment possibilities. This work is completed. See RRTAC Report 81-3.

7.2 MOUNTAINS AND FOOTHILLS RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Forestry, Wildlife and Watershed Capabilities

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
	Design and construction of stable spoil dumps	A survey was conducted of existing reclaimed dumps in Alberta and British Columbia to identify practical resloping strategies. A study of erosion of a variety of dump slopes was conducted. See RRTAC Report 87-8.
Landscape Design	Erosion control	Mulches, binders and contouring techniques for erosion control on coal spoil were evaluated.
	Water management	Settling pond size requirements, the scientific basis for water quality objectives, and methods for predicting sediment production were reviewed and evaluated. See RRTAC Reports 86-2, 87-5, 87-6.
	For various land uses	A literature review and evaluation of soil reconstruction requirements was completed. See RRTAC Report 87-2.
Soil Reconstruction	For reclamation of ash dumps	Thickness of soil required over coal ash to support vegetation was investigated.
	Species selection	Development, assessment and field testing of native grasses for reclamation is ongoing.
Revegetation	Propagation	Methods for propagation of reclamation shrubs were assessed.
	Establishment	Methods for establishment of tree seedlings in grass cover were evaluated.

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
	Fertilization, nutrients	Studies identified treatments important to development of self-sustaining plant cover.
Revegetation (Cont.)	Growth	A method for early prediction of tree growth suitability was developed. See RRTAC Report 88-7.
Wildlife Habitat	Techniques Assessment methods	Literature reviews of methods for wildlife habitat reclamation and measurement of reclamation success were completed. See RRTAC Reports 86-9, 88-1.

7.3 OIL SANDS RECLAMATION RESEARCH PROGRAM

Objective: Restoration of Forestry, Wildlife Capabilities and Erosion Control

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Soil Reconstruction on Tailings	Identify recipes for reconstructed soils suitable for: - Commercial forest - Non-commercial forest - Erosion control - Wildlife habitat	Identification of the chemical and microbiological properties of peat, and development of mycorrhizal innoculants for jack pine and other woody species. See RRTAC Reports 84-4, 88-3, 88-5. Identification of soil amendment requirements. See RRTAC Report 83-1. This study was fundamental in designing the oil sand soil reconstruction plots which were constructed in 1983.
Revegetation	- Selection - Propagation - Establishment - Management - Sampling	These projects consisted of literature reviews on tree and shrub selection, seed collection, propagation techniques, and sampling methods for use on the soil reconstruction plots. See RRTAC Reports 83-5, 84-2.

7.4 OIL & GAS RECLAMATION RESEARCH PROGRAM

Objective: To develop safe methods of waste disposal and return land to a condition capable of sustaining a designated land use.

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Materials Handling	Identify the best methods for handling soil materials in pipeline construction in agricultural land	A survey was made of pipelines of various ages on all of our major agricultural soil types. Material handling methods were assessed and problem areas identified. See RRTAC Report 83-3.
Drilling Muds	Disposal of drilling muds	A literature review of disposal methods for KCl drilling muds was undertaken. See RRTAC Report 87-1.
	Sumps	A review of clay liners for containment of drilling wastes was completed. See RRTAC Report 88-10. A study was completed assessing the feasibility of developing a computer system for evaluating a proposed sump location.

7.5 GENERAL*

PROBLEM AREA	RESEARCH PRIORITIES	DESCRIPTION
Reclamation Bibliography and Review	Document the findings of reclamation research activities and assess implications for Alberta operations	Worldwide reclamation literature has been reviewed and condensed for presentation in a report which lists and discusses existing information pertinent to reclamation in Alberta. The bibliographic data base is accessable through the University of Alberta computing system. See RRTAC Reports 82-1, 84-1.
Workshops	Conduct workshops to determine research needs in Alberta and to disseminate research findings	See RRTAC Reports 80-4 (Forest Soils), 81-3 (Coal Ash), 83-4 (Eastern Slopes Hydrology), 85-1 (Revegetation in Mountains/Foothills) and 87-3 (Gel and Saline Drilling Wastes).
Reference	Provide sources of information for reclamationists	See RRTAC Reports 80-5 (Plant Species Manual), 81-2 (Survey of Activities), and 82-2 (Bibliography of Soils, Geology, Hydrology and Groundwater).

* Projects with province-wide application.

8. 1988/89 RECLAMATION RESEARCH BUDGET

Project No.	Project	1988/89 Budget ($)
PLAINS COAL RECLAMATION RESEARCH PROGRAM		
78-20	Can-Ag Enterprises Ltd. Battle River Soil Reconstruction Project	40 000.00
82-24	Monenco Consultants Ltd. Highvale Soil Reconstruction Project	40 431.00
OIL SANDS RECLAMATION RESEARCH PROGRAM		
83-07	Hardy BBT Limited Oil Sands Soil Reconstruction Project	55 000.00[1]
OIL & GAS RECLAMATION RESEARCH PROGRAM		
86-32B	Alberta Environmental Centre Soil Compaction	43 509.00[2]
86-33	Alberta Research Council Drilling Muds Disposal	50 000.00[3]
GENERAL PROGRAM		
88-1	Concord Scientific Corporation Future Research Needs	22 500.00
88-2	Hardy BBT Limited Update of Plant Species Suitability Manual	14 833.00[4]
	Publications	13 539.00
	TOTAL RRTAC	$ 279 812.00
	TOTAL CO-FUNDING AGENCIES	127 985.00
	GRAND TOTAL	$ 407 797.00

Co-funding Agencies

1 Syncrude Canada Ltd. ($21 000)
2 Alberta Environmental Centre ($56 375)
3 Alberta Research Council ($40 610)
4 Recreation, Parks and Wildlife Foundation ($10 000)

RRTAC funds are provided by the Alberta Heritage Savings Trust Fund.

9. COMMITTEE MEMBERSHIP

9.1 RECLAMATION RESEARCH TECHNICAL ADVISORY COMMITTEE MEMBERS

The members of RRTAC are:

Chris Powter (Chairman)	Alberta Environment
Sharon Guenette (Secretary)	Forestry, Lands & Wildlife
Reinhard Hermesh	Alberta Environmental Centre
David Lloyd	Forestry, Lands & Wildlife
Leon Marciak	Alberta Agriculture
Steve Moran	Aberta Research Council
Harry Sahay	Alberta Energy
Sam Takyi	Forestry, Lands & Wildlife
Hugh Wollis	Forestry, Lands & Wildlife

9.2 MOUNTAINS & FOOTHILLS RECLAMATION RESEARCH PROGRAM COMMITTEE MEMBERS

The members of MFRRP Committee are:

Chris Powter (Chairman)	Alberta Environment
Gerald Acott	Cardinal River Coals Ltd.
Marcellus Adamkewicz	OBED Mountain Coal Company Limited
Vern Betts	Smoky River Coal Ltd.
Jeff Bondy	Forestry, Lands & Wildlife
Curtis Brinker	Luscar Sterco (1977) Ltd.
Ken Crane	Luscar Ltd.
Reinhard Hermesh	Alberta Environmental Centre
Al Kennedy	ESSO Resources Canada Ltd.
Bernd Martens	Manalta Coal Ltd.
Fred Munn	Cardinal River Coals Ltd.
Marlin Murphy	Gregg River Resources Ltd.
Tom Sneddon	Energy & Natural Resources
Bruce Stubbs	Forestry, Lands & Wildlife
Dave Townsend	Crows Nest Resources

9.3 OIL & GAS RECLAMATION RESEARCH PROGRAM COMMITTEE MEMBERS

The members of OGRRP Committee are:

Chris Powter (Chairman)	Alberta Environment
Roger Creasy	Energy Resources Conservation Board
James Fijikawa	Alberta Environment
Arnold Janz	Alberta Environment
Fred Kuipers	Peace Pipe Line Ltd.
David Lloyd	Forestry, Lands & Wildlife
Leon Marciak	Alberta Agriculture
Doug Mead	Shell Canada Resources Limited

Gary Mott	Bow Valley Industries Ltd.
Sam Takyi	Forestry, Lands & Wildlife

9.4 OIL SANDS RECLAMATION RESEARCH PROGRAM COMMITTEE MEMBERS

The members of the OGRRP Committtee are:

Chris Powter (Chairman)	Alberta Environment
Al Fedkenheuer	NOVA Corporation of Alberta
Tony Dai	Syncrude Canada Ltd.
Al Kennedy	ESSO Resources Canada Limited
Paul Layte	Alberta Environmental Centre
Doug Mead	Shell Canada Resources Limited
Sam Takyi	Forestry, Lands & Wildlife
Steve Tuttle	Suncor Inc.

9.5 PLAINS COAL RECLAMATION RESEARCH PROGRAM COMMITTEE MEMBERS

Chris Powter (Chairman)	Alberta Environment
Yeh Moon Chae	Alberta Environment
John Dormaar	Agriculture Canada Research Station
Katherine Gizikoff	Manalta Coal Ltd.
Richard Johnson	Alberta Environmental Centre
Jivan Kayande	Alberta Power Limited
Chong Ko	Alberta Environment
Dermot Lane	Fording Coal Ltd.
Bob Logan	Luscar Ltd.
Phil Lulman	TransAlta Utilities Corp.
Leon Marciak	Alberta Agriculture

10. RECLAMATION RESEARCH REPORTS

** 1. RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp.

DESCRIPTION: This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

** 2. RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi, and H.F. Regier. 160 pp.

DESCRIPTION: Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

N/A 3. RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker, and D.F. Polster. 2 vols, 541 pp.

DESCRIPTION: Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

* 4. RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp.

DESCRIPTION: This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

** 5. RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch, and G. Lutwick. 253 pp.

DESCRIPTION: Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

N/A 6. RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp.

DESCRIPTION: Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

N/A 7. RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology, and Groundwater. C.B. Powter and H.P. Sims. 97 pp.

DESCRIPTION: This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

N/A 8. RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp.

DESCRIPTION: Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials.

N/A 9. RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp.

DESCRIPTION: Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

** 10. RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz. 123 pp.

DESCRIPTION: Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

N/A 11. RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp.

DESCRIPTION: This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

*** 12. RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter, and J.A. Campbell. 2 vols, 1549 pp.

DESCRIPTION: Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

** 13. RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp.

DESCRIPTION: This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

* 14. RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

** 15. RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser, and J.C. Zak. 2 vols, 676 pp.

DESCRIPTION: This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

** 16. RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz. 416 pp.

DESCRIPTION: Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

* 17. RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

** 18. RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp.

DESCRIPTION: The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

** 19. RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp.

DESCRIPTION: Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

* 20. RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp.

DESCRIPTION: In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

** 21. RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp.

DESCRIPTION: This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

** 22. RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp.

DESCRIPTION: This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

* 23. RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp.

DESCRIPTION: The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta

* 24. RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp.

DESCRIPTION: This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

* 25. RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

** 26. RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp.

DESCRIPTION: This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

N/A 27. RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp.

DESCRIPTION: Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

** 28. RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp.

DESCRIPTION: This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

** 29. RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (compiler). 218 pp.

DESCRIPTION: Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

* 30. RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp.

DESCRIPTION: This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

* 31. RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp.

DESCRIPTION: The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

** 32. RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp.

DESCRIPTION: The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

* 33. RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp.

DESCRIPTION: The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

* 34. RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp.

DESCRIPTION: This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

** 35. RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Areas. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp.

DESCRIPTION: This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

** 36. RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps.

DESCRIPTION: The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

** 37. RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp.

DESCRIPTION: The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

** 38. RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp.

DESCRIPTION: This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

* 39. RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp.

DESCRIPTION: This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

** 40. RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix.

DESCRIPTION: The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for

certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

** 41. RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (compiler). 135 pp.

DESCRIPTION: Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

** 42. RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N_2-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp.

DESCRIPTION: The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their uninoculated counterparts.

** 43. RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp.

DESCRIPTION: This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

** 44. RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.H. Danielson and S. Visser. 177 pp.

DESCRIPTION: The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

* 45. RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp.

DESCRIPTION: This annual report describes the expenditure of $500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

* 46. RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp.

DESCRIPTION: Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

** 47. RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey, Alberta Forest Service. 4 Sections, various pagings.

DESCRIPTION: Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

** 48. RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe, SIMCO Groundwater Research Ltd. 78 pp.

DESCRIPTION: Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological

parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

* 49. RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk, 1988. 61 pp.

DESCRIPTION: The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

** 50. RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek, Monenco Consultants Limited. 104 pp.

DESCRIPTION: This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

* 51. RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp.

DESCRIPTION: The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

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